TECHNICAL ASSISTANCE TO IDENTIFY THE MOST SUITABLE DIRECT USE APPLICATIONS AND TECHNOLOGIES IN LOW-TO-MEDIUM TEMPERATURE GEOTHERMAL SYSTEMS IN SIX AFRICAN COUNTRIES

CTCN REQUEST REF: 2019000050

DELIVERABLES #3/4: SECOND/THIRD PROGRESS REPORTS

CATEGORIZATION AND ECONOMIC ASSESSMENT OF COMMERCIAL VIABILITY OF IDENTIFIED GEOTHERMAL DIRECT USE TECHNOLOGIES

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ABBREVIATIONS & ACRONYMS

CAPEX	Capital Expenditure
CTCN	Climate Technology Center and Network
DJF	Djiboutian Franc
EDCL	Rwanda Energy Development Corporation Limited
ETB	Ethiopian Birr
IRR	Internal Rate of Return
KenGen	Kenya Electricity Generating Company PLC
KES	Kenyan Shilling
Kg	Kilogram
LPG	Liquefied Petroleum Gas
MEMD	Ministry of Energy and Mineral Development (Uganda)
MoMP	Ministry of Mines and Petroleum, Geothermal Resources Directorate (Ethiopia)
O&M	Operations and Maintenance
ODDEG	Office Djiboutien de Développement de l'Énergie Géothermique (Djibouti Geothermal Energy Development Authority)
OPEX	Operating Expenditure
RWF	Rwandan Franc
SGS	Steam Gathering System
SWOT	Strength-Weaknesses-Opportunities-Threats
TGDC	Tanzania Geothermal Development Company Limited
TZS	Tanzanian Shilling
UGX	Ugandan Shilling
USD	United States Dollar

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INTRODUCTION

A. Context for the Assignment

To date, the focus of utilizing geothermal resources in East Africa has been for power generation, as this technology offers a clean source of baseload power that reduces emissions and improves energy security. However, there is also significant untapped potential for direct use applications of geothermal energy, particularly in the agricultural sector, which is a key driver of economic activity across the region. In this context, the objective of this assignment is to provide specialized technical assistance (TA) services to the Climate Technology Center and Network (CTCN) to identify potential geothermal direct use applications in six East African countries – Djibouti, Ethiopia, Kenya, Rwanda, Tanzania and Uganda. The services aim to inform policymakers in each country to improve their understanding of opportunities for direct use geothermal projects from technical, financial and market viability perspectives. The TA will be provided to the CTCN National Designated Entity (NDE) in each country, along with Project Proponents:

- Djibouti Geothermal Energy Development Authority (Office Djiboutien de Développement de l'Énergie Géothermique, ODDEG)
- Ethiopian Ministry of Mines and Petroleum, Geothermal Resources Directorate (MoMP)
- Kenya Electricity Generating Company PLC (KenGen), Geothermal Development Division
- Rwanda Energy Development Corporation Limited (EDCL)
- Tanzania Geothermal Development Company Limited (TGDC)
- Uganda Ministry of Energy and Mineral Development (MEMD)

In each country, the TA aims to identify potential direct use geothermal applications as well as the corresponding sectors and technologies that are best suited to benefit from the utilization of direct use geothermal projects. The TA will also establish the economic and market viability of the identified direct use projects. In addition to supporting rural livelihoods and economic development, this project will also support each country's efforts to advance its climate commitments given the impact of geothermal development on energy sector decarbonization.

B. Second and Third Progress Reports (Deliverable #2 and #3)

This report builds upon the work completed to date under this assignment – i.e., the First Progress Report deliverable. **Section I** of this report corresponds to the **Second Progress Report** deliverable, which is a summary of the categorized geothermal direct use technologies for the geothermal sites identified in the six project countries. **Section II**, which corresponds to the **Third Progress Report** deliverable, is a market and economic assessment of the commercial viability of the identified direct use technologies and projects. **Annex 1** provides a summary of the methodology used in the commercial/economic analysis of the categorized direct use projects.

NB: Due to the limited nature of the scope of work, as well as other constraints on international and domestic travel associated with the global COVID-19 pandemic, the findings in this report should only be considered a **pre-feasibility study**. The data presented in this report is intended to provide a baseline for future research and more comprehensive/technical feasibility studies.

I. CATEGORIZATION OF DIRECT USE GEOTHERMAL TECHNOLOGIES AT THE IDENTIFIED SITES

This section presents an overview of the geothermal direct use technologies and projects that have been identified and categorized according to their commercial and technical viability for development at the identified geothermal sites in each of the six project countries. This builds on the work previously carried out by the project team, during which feedback was obtained from local community stakeholders to (i) review the primary livelihood and economic activities in each community; (ii) identify areas of potential thermal demand that could benefit from geothermal heating applications; and (iii) categorize possible opportunities for direct use projects accordingly (**Table 1**).[1]

Table 1: Categorized Geothermal Direct Use Applications by Site

Geothermal Site	Categorized Direct Use Applications
DJIBOUTI	
Ambado PK-20	1. Vegetable/grain drying
Asal Fialé	1. Vegetable/grain drying 2. Fish drying 3. Balneotherapy
Hanle Garabbayis	1. Vegetable/grain drying 2. Balneotherapy 3. Fruit drying
ETHIOPIA	
Aluto-Langano	1. Fish drying 2. Greenhouse heating 3. Balneotherapy
Dubti	1. Vegetable/grain drying 2. Fruit drying 3. Fish drying
Abaya	1. Fish drying 2. Tobacco curing
KENYA	
Olkaria	1. Fish drying 2. Chicken hatchery
Eburru	1. Pyrethrum drying 2. Fruit drying
Menengai	1. Vegetable/grain drying 2. Greenhouse heating
RWANDA	
Bugarama	1. Fish drying 2. Tea processing
Gisenyi	1. Vegetable/grain drying 2. Fish drying

[1] Each of the six Project Proponents – ODDEG, MoMP, KenGen, EDCL, TGDC and MEMD – have reviewed and approved the categorized list of direct use applications listed in **Table 1** (see **Progress Report #1** under this assignment's scope of work for more information).

Karago	1. Vegetable/grain drying 2. Milk pasteurization
TANZANIA	
Kiejo-Mbaka	1. Vegetable/grain drying 2. Fish drying 3. Milk pasteurization 4. Balneotherapy 5. Tea processing 6. Greenhouse heating
UGANDA	
Kibiro	1. Vegetable/grain drying 2. Balneotherapy
Buranga	1. Fish drying 2. Tea processing 3. Balneotherapy
Panyimur	1. Fruit drying 2. Tea processing 3. Rice drying 4. Fish drying

Source: Community surveys; Stakeholder interviews; GreenMax Capital Advisors analysis

Direct use applications using geothermal heat can be broadly defined based on the activity required:

- ✓ **Drying** – geothermal drying is commonly applied to dry agricultural produce such as fruits, vegetables, fish and grains (rice), as well as other products such as tea and tobacco leaves. The drying process (which is commonly performed using solar energy) aims to reduce the risk of the product spoiling and in turn to allow it to have a longer shelf life. Many products that require drying retain a large quantity of water; the drying process may reduce the level of humidity from approximately 80% to 20%. This process relies on providing enough energy to deal with the latent heat of water. In principle, the process evaporates the water contained in the product by applying heat energy at constant temperature.

- ✓ **Heating** – geothermal heat can replace fossil fuels or biomass/wood fuels across a wide ranging of applications. In the agricultural sector, heating can support certain processes in the production and processing of agricultural products. Examples include greenhouse heating (can also be used to grow flowers), fish farms, milk pasteurization and chicken hatcheries, among others. Applying heat and controlling temperature for such processes can lead to increased productivity and yield, as well as reduced disease, among other benefits. For instance, fish farms with higher temperature will yield more fish. Outside of the agricultural sector, the most common application for geothermal heat is in spas/hot springs.

II. MARKET AND ECONOMIC ASSESSMENT OF COMMERCIAL VIABILITY OF THE IDENTIFIED DIRECT USE GEOTHERMAL TECHNOLOGIES

This section covers the market and commercial viability assessment of the identified direct use geothermal technologies and projects at each identified site, including:

- An estimate of the expected costs of the identified geothermal direct use technologies;
- A cost comparison of the identified geothermal direct use technologies vis-à-vis conventional systems; and
- A business/financial model for each selected geothermal direct use technology.

A detailed financial analysis of each selected technology listed in **Table 1** was conducted to determine its commercial viability and its ability to provide attractive returns to investors. In conducting this analysis, a full financial model was developed for all the selected applications. The financial model is an interactive MS Excel model with no use of macros to enable users to easily vary the inputs. It consists of input sheets (model assumptions)/sensitivity analysis sheets, computational sheets, and results sheets. While all the calculations in the model are shown in USD for ease of comparison across the various countries, the model excludes foreign exchange fluctuation considerations as it is assumed that the projects will be financed in local currency and the project cashflows will all be in local currency. The model is included as an **Appendix** to this report while the model assumptions are detailed in **Annex 1.**

Two different approaches were taken in the financial analysis of the selected direct use applications based on data gathered through stakeholder consultations in each of the six project countries. The first set of applications was analyzed as greenfield projects while the remaining applications were analyzed as retrofits. Fish drying, vegetable/grain drying, fruit drying, pyrethrum drying, rice drying and balneotherapy applications were analyzed as greenfield projects, while tea processing, tobacco curing, greenhouse heating, chicken hatcheries and milk processing were analyzed as retrofits.

For the greenfield projects, it was assumed that the various plants/facilities will be built from scratch. Hence, the capital costs include the cost of building the facilities in addition to the cost of the geothermal resource – cost of exploration and drilling production/injection wells and the steam gathering system (SGS) and associated equipment. The operating costs include cost of goods sold, electricity costs, labor costs, operation and maintenance (O&M) costs, overhead costs etc., while revenue is derived from the sales of the finished products.

For the retrofits, it was assumed that the various plants/facilities are already in place and currently utilizing fossil fuel sources. Hence, the capital costs include only the cost of the geothermal field, SGS and associated equipment, as well as the costs of any modifications to the facility to convert it from being heated by burning fossil fuels to be heated by geothermal resources. The operating costs include only the O&M cost of the geothermal field and retrofits (not including the regular operating costs of the facilities), while the cost savings realized because of the retrofit represent the project's revenue.

In addition to the financial analysis to determine the viability of the various applications, a cost comparison analysis was also conducted to compare the cost of using geothermal heat to the cost of the identified conventional systems applicable to each project. The cost comparison analysis considered costs associated with the construction and operational phases of the projects. The costs associated with construction include the capital/equipment costs. The operating costs include fuel and electricity costs, labor costs and maintenance costs. For the food drying applications, the implicit cost of lost revenue due to inability to charge premium price due to poor taste, quality etc. because of the drying system utilized was also incorporated into the analysis. It should also be noted that the analysis does not include the cost/benefits of the environmental, health and social impacts of the energy systems considered, which would further favor geothermal energy given that it is a clean, renewable resource.

Furthermore, a sensitivity analysis was conducted to determine the impact of change in key assumptions on the equity internal rate of return (IRR) as a measure of the viability of the projects analyzed. The results of the analysis have been color-coded such that scenarios with equity IRR greater than 15% (which is considered attractive) are shown in green, while those between 10-14.9% (which is considered manageable) are shown in yellow, while those below 10% and negative (which is considered unfavorable) are shown in red (scenarios with results showing as "NEG IRR" mean that the negative value is too small to be displayed).[2]

NOTE:

- All sources and assumptions for the analysis in Section II are detailed in the financial model, which is included as an Appendix to this report
- In the tables throughout this report, a plain white cell refers to a calculated value, while a cell with blue colored text refers to a hard-coded input (see Annex 1).

[2] "CrossBoundary Energy fully exits first fund at 15% net internal rate of return (IRR), raises $40M to continue to scale financed solar for businesses in Africa," Crossboundary Energy, (17 November 2020): https://www.crossboundary.com/wp-content/uploads/2020/11/CBE-Press-Release-20201117_FINAL.pdf; and
"Nigeria Mini-Grid Investment Brief," Rural Electrification Agency: (December 2017): https://rea.gov.ng/Nigeria_MinigridInvestmentBrief_171202-V2.pdf

2.1 DJIBOUTI

Geothermal Site	Categorized Direct Use Applications
Ambado PK-20	1. Vegetable/grain drying
Asal Fialé	1. Vegetable/grain drying 2. Fish drying 3. Balneotherapy
Hanle Garabbayis	1. Vegetable/grain drying 2. Balneotherapy 3. Fruit drying

2.1.1 ***Direct Use Geothermal Project**: VEGETABLE/GRAIN DRYING (Greenfield)* ***Applicable Sites**: Ambado PK-20, Asal Fiale, Hanle Garabbayis*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal vegetable drying plant with a 1-ton/batch capacity is estimated at USD 270,470 (**Table 2**).

Table 2: Geothermal Vegetable Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Construction	60,000
Batch Dryer	65,000
Land Acquisition Cost	-
Blanching machine	3,000
Pre-cooling machine	30,000
Packaging equipment	10,970
Total CAPEX ($ USD)	**270,470**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 287,005 (**Table 3**).

Table 3: Geothermal Vegetable Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Cost of Fresh Veg (incl. Transport)	US$/Kg	0.32	177,898
Electricity Costs	US$/kwh	0.23	25,655
Equipment O&M	% of CAPEX	10.0%	27,047
Labor (Non-payroll)	US$/hr	0.82	17,211
Payroll	US$/Yr	N/A	18,127
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	1,451
Distribution/Marketing Expenses	% of Rev	0.5%	1,451
Utilities, Property Tax	US$/sqft	2.0	10,764
Packaging	US$/Kg	0.09	7,309
Opex Annual Inflator (%)		1%	
TOTAL OPEX			287,005

Cost Comparison

A cost comparison analysis was conducted to compare the cost of a geothermal vegetable drying plant to the cost of identified conventional vegetable drying systems including open air sun drying, solar drying and wood-fired drying systems. **Table 4** presents the results of the analysis showing the total annualized cost of each system.

Table 4: Vegetable Drying Energy Systems Cost Comparison

	VEGETABLE DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	5.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	300	600	600	600
Max Annual Capacity per Dryer (Kg)	1,500.0	600,000.0	600,000.0	600,000.0
Volume of Veg Processed per Year (Kg)	550,000	550,000	550,000	550,000
No. of Dryers Required	367.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$158,000.00	$226,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$22,020.00**	**$4,414.40**	**$7,900.00**	**$9,060.00**
Fuel Requirement (kg/Yr)	-	-	79,019.35	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.11	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$8,692.13**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.23	0.23
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$25,654.72**	**$25,654.72**
Annual Op Costs - Labour ($/Yr)	**$21,513.57**	**$17,210.86**	**$21,513.57**	**$17,210.86**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$11,010.00**	**$8,828.80**	**$15,800.00**	**$22,650.00**
Cost of Lost Revenue ($/Yr)	**$145,109.25**	-	-	-
Total Annualized Costs ($/Yr)	**$199,652.82**	**$30,454.06**	**$79,560.42**	**$74,575.57**
Total Annual Costs Savings ($/Yr)	**$125,077.25**	**-$44,121.52**	**$4,984.84**	
Total Annual Costs Savings (%)	**63%**	**-145%**	**6%**	

The analysis found that solar drying has the least total annualized costs, followed by geothermal direct-use, wood-fired dryers and open-air sun drying. Switching to geothermal energy will result in costs savings of 6% and 63% compared to wood-fired and open-air sun drying, respectively.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the vegetable drying application, based on the assumptions detailed in **Annex 1**, found that the project is not viable with a negative IRR, as the cashflows projected to be generated over the life of the plant at the assumed production level will be insufficient to pay back the initial investment. As shown in **Table 5**, the average annual revenue generated by the plant of USD 325,811 is only slightly higher than projected average annual expenses of USD 324,237. The total loss to be incurred by investors over the life of the plant is estimated at USD 367,348.

Table 5: Geothermal Vegetable Drying Analysis Results

VEG DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	78,178
Avg Annual Revenue	$325,810.56
Avg Annual Expenses	$324,237.33
Avg EBITDA	$1,732.17
Total CF to Equity	-$286,207
Net CF to Equity	-$367,348
Cash on Cash Return	-4.53x
After Tax Equity IRR	NEG IRR
After Tax Project IRR	-16.89%
Payback Year	#N/A

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 6 shows the impact of increases in CAPEX and the quantity of fresh vegetables processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the geothermal vegetable drying plant will only be viable if CAPEX decreases by 40% and processing volume increases to 600,000kg.

Table 6: Geothermal Vegetable Drying CAPEX Scenarios

		CAPEX						
		$162,282	$216,376	$270,470	$324,564	$378,658	$432,752	$486,846
Quantity (Kg)	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
	300,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	350,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	400,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	450,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	500,000	-5.10%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	550,000	3.51%	-5.60%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	600,000	10.68%	1.20%	-5.89%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

  ✓ ***OPEX Scenarios***

Table 7 shows the impact of increases in OPEX and the quantity of fresh vegetable processed at 20% and 50,000kg intervals, respectively, on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal vegetable drying plant will be viable at the current production level if OPEX decreases by 20%.

Table 7: Geothermal Vegetable Drying OPEX Scenarios

		OPEX						
		$172,203	$229,604	$287,005	$344,406	$401,807	$459,208	$516,609
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	17.32%	-9.11%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	350,000	27.71%	0.52%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	400,000	39.73%	7.29%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	450,000	52.71%	13.73%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	500,000	66.10%	20.74%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	550,000	79.65%	28.72%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	600,000	93.24%	37.56%	-5.89%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 8 shows the impact of increases in the price of dried vegetables and the quantity of fresh vegetables processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX. The results also reveal that the geothermal vegetable drying plant will be viable at the current production level if prices increase by 20%. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable at the production levels analyzed.

Table 8: Geothermal Vegetable Drying Price Scenarios

		Price						
		$2.21	$2.95	$3.69	$4.43	$5.17	$5.90	$6.64
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	9.11%	30.25%	57.44%
	350,000	NEG IRR	NEG IRR	NEG IRR	-3.43%	19.90%	49.55%	83.01%
	400,000	NEG IRR	NEG IRR	NEG IRR	4.72%	32.98%	70.14%	108.75%
	450,000	NEG IRR	NEG IRR	NEG IRR	12.04%	47.93%	91.01%	134.52%
	500,000	NEG IRR	NEG IRR	NEG IRR	19.77%	63.69%	111.93%	160.28%
	550,000	NEG IRR	NEG IRR	NEG IRR	28.68%	79.69%	132.87%	186.03%
	600,000	NEG IRR	NEG IRR	-5.89%	38.68%	95.77%	153.79%	211.79%

In summary, the geothermal vegetable drying plant is estimated to be unviable based on the current set of assumptions mainly due to the high OPEX values. However, it is clear from the sensitivity analysis that the plant can be made viable by adopting cost cutting measures to minimize OPEX and/or sell the dried produce at higher prices.

2.1.2 ***Direct Use Geothermal Project:*** *FISH DRYING (Greenfield)*
Applicable Sites: *Asal Fialé*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal fish drying plant with a 1-ton/batch capacity is estimated at USD 264,470 (**Table 9**).

Table 9: Geothermal Fish Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Constr. Of Drying Station	150,000
Drying Cabinet	2,000
Packaging equipment	10,970
Land Acquisition Cost	-
Total CAPEX ($ USD)	**264,470**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 535,769 (**Table 10**). The cost of fresh fish and pricing are based on figures from Rwanda.

Table 10: Geothermal Fish Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	*Units*	Cost/Unit	1st Year (USD)
Cost of Fresh Fish (incl. Transport)	US$/Kg	1.50	450,000
Electricity Costs	US$/kwh	0.23	13,993
Equipment O&M	% of CAPEX	10.0%	26,447
Labor (Non-payroll)	US$/hr	0.82	14,752
Payroll	US$/Yr	N/A	18,127
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	2,854
Distribution/Marketing Expenses	% of Rev	0.5%	2,854
Utilities, Property Tax	US$/sqft	2.0	3,582
Packaging	US$/Kg	0.05	3,067
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**535,769**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal fish drying to the cost of identified conventional fish drying systems including open air sun drying, solar drying, and wood-fired systems. **Table 11** presents the results of the analysis showing the total annualized cost of each system.

Table 11: Fish Drying Energy Systems Cost Comparison

	FISH DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	10.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	150	300	300	300
Max Annual Capacity per Dryer (Kg)	1,500.0	300,000.0	300,000.0	300,000.0
Volume of Fish Processed per Year (Kg)	300,000	300,000	300,000	300,000
No. of Dryers Required	200.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$185,000.00	$253,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$12,000.00**	**$4,414.40**	**$9,250.00**	**$10,140.00**
Fuel Requirement (kg/Yr)			39,135.66	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.11	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$4,304.92**	**$0.00**
Electricity Requirement (kWh/Kg)			0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.23	0.23
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$13,993.48**	**$13,993.48**
Annual Op Costs - Labour ($/Yr)	**$18,440.20**	**$14,752.16**	**$18,440.20**	**$14,752.16**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$6,000.00**	**$8,828.80**	**$18,500.00**	**$25,350.00**
Cost of Lost Revenue ($/Yr)	**$285,450.00**	-	-	-
Total Annualized Costs ($/Yr)	**$321,890.20**	**$27,995.36**	**$64,488.61**	**$64,235.64**
Total Annual Costs Savings ($/Yr)	**$257,654.56**	**-$36,240.28**	**$252.96**	
Total Annual Costs Savings (%)	**80%**	**-129%**	**0.4%**	

The analysis found that solar drying has the least total annualized costs, followed by geothermal direct-use, wood-fired dryers and open-air sun drying. Switching to geothermal energy will result in costs savings of 0.4% and 80% compared to wood-fired dryers and open-air sun drying, respectively.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the fish drying application, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is moderate with an after-tax equity IRR of 11.04%, payback period of 13 years and an after-tax project IRR of 11.15%. As shown in **Table 12**, the average annual revenue generated by the plant is USD 640,738, while average total annual expenses are USD 605,273. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 446,075, while net cashflows to be distributed is USD 366,734.

Table 12: Geothermal Fish Drying Analysis Results

FISH DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	65,604
Avg Annual Revenue	$640,738
Avg Annual Expenses	$605,273
Avg EBITDA	$35,465
Total CF to Equity	$446,075
Net CF to Equity	$366,734
Cash on Cash Return	4.62x
After Tax Equity IRR	11.04%
After Tax Project IRR	11.15%
Payback Year	13

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 13 shows the impact of increases in CAPEX and the quantity of fresh fish processed at 20% and 25,000 intervals, respectively, on the equity IRR. The results show that the geothermal fish drying plant will not be viable if CAPEX increases by 20% and above at the production levels analyzed.

Table 13: Geothermal Fish Drying CAPEX Scenarios

		CAPEX						
		$158,682	$211,576	$264,470	$317,364	$370,258	$423,152	$476,046
	11.04%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	-8.22%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	1.66%	-8.55%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	8.82%	-0.53%	-8.75%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	225,000	15.78%	5.03%	-1.88%	-8.88%	NEG IRR	NEG IRR	NEG IRR
	250,000	23.63%	10.21%	2.71%	-2.82%	-8.97%	NEG IRR	NEG IRR
	275,000	32.52%	15.43%	6.98%	1.13%	-3.51%	-9.04%	NEG IRR
	300,000	42.20%	21.15%	11.04%	4.75%	-0.03%	-4.08%	-9.09%

✓ ***OPEX Scenarios***

Table 14 shows the impact of increases in OPEX and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal fish drying plant will not be viable if OPEX increases by 20% and above at the production levels analyzed.

Table 14: Geothermal Fish Drying OPEX Scenarios

		OPEX						
		$321,461	$428,615	$535,769	$642,922	$750,076	$857,230	$964,383
	11.04%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	75.72%	24.00%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	97.45%	35.93%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	119.21%	49.11%	-8.75%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	225,000	140.97%	62.84%	-1.88%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	162.74%	76.77%	2.71%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	275,000	184.50%	90.77%	6.98%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	300,000	206.25%	104.79%	11.04%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 15 shows the impact of increases in the price of dry fish and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results also reveal that the geothermal fish drying plant will not be viable if prices decrease by 20% and above at the production levels analyzed. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable if the quantity of fresh fish processed falls below 300,000kg.

Table 15: Geothermal Fish Drying Price Scenarios

		Price						
		$5.19	$6.92	$8.65	$10.38	$12.11	$13.84	$15.57
	11.04%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	NEG IRR	NEG IRR	NEG IRR	22.76%	72.74%	126.19%	179.67%
	175,000	NEG IRR	NEG IRR	NEG IRR	35.58%	96.80%	159.20%	221.57%
	200,000	NEG IRR	NEG IRR	-8.75%	49.89%	120.90%	192.20%	263.46%
	225,000	NEG IRR	NEG IRR	-1.88%	64.80%	145.00%	225.20%	305.35%
	250,000	NEG IRR	NEG IRR	2.71%	79.92%	169.09%	258.19%	347.24%
	275,000	NEG IRR	NEG IRR	6.98%	95.10%	193.19%	291.17%	389.12%
	300,000	NEG IRR	NEG IRR	11.04%	110.29%	217.28%	324.16%	431.01%

In conclusion, the geothermal fish drying plant is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that a slight increase in CAPEX/OPEX or decrease in prices will make the plant unviable. In addition, the projected investor returns are moderate and could become more attractive if the project is supported by a grant and/or concessional debt with much lower interest rate than the 11.3% assumed.

2.1.3 ***Direct Use Geothermal Project***: *BALNEOTHERAPY / GEOTHERMAL SPA (Greenfield)* ***Applicable Sites:*** *Asal Fialé, Hanle Garabbayis*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal spa with a 1,000-person/use capacity is estimated at USD 881,700 (**Table 16**).

Table 16: Geothermal Spa Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	10,500
Well Drilling & Pipes	565,000
Constr. Of Spa	286,200
Land Acquisition Cost	-
Total CAPEX ($ USD)	**881,700**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 148,615 (**Table 17**).

Table 17: Geothermal Spa Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Towel Supply and Laundry Costs	US$/Unit	3.38	3,380
Electricity Costs	US$/kwh	0.23	13,812
Equipment O&M	% of CAPEX	10.0%	88,170
Labor (Non-payroll)	US$/hr	0.82	19,414
Payroll	US$/Yr	N/A	18,127
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	657
Marketing Expenses	% of Rev	0.5%	657
Spa Building Utility Costs	US$/sqft	2.0	4,306
Opex Annual Inflator (%)		1%	
TOTAL OPEX			148,615

Cost Comparison

Balneotherapy is based on hot brine provided by geothermal resources only; hence, a cost comparison is not applicable.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the geothermal spa, based on the assumptions detailed in **Annex 1**, found that the project is unviable with a negative IRR as the cashflows projected to be generated over the life of the spa at the assumed level of ticket sales will be insufficient to pay back the initial investment. As shown in **Table 18**, the average annual revenue generated by the spa of USD 148,431 is less than the projected average total annual expenses of USD 167,894. The total loss to be incurred by investors over the life of the plant is estimated at USD 1.81 million.

Table 18: Geothermal Spa Analysis Results

GEOTHERMAL SPA RESULTS SUMMARY	
Avg Annual Sales (Tickets)	14,000
Avg Annual Revenue	$148,431.01
Avg Annual Expenses	$167,894.01
Avg EBITDA	#DIV/0!
Total CF to Equity	-$1,547,791
Net CF to Equity	-$1,812,301
Cash on Cash Return	-6.85x
After Tax Equity IRR	NEG IRR
After Tax Project IRR	#NUM!
Payback Year	#N/A

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 19 shows the impact of increases in CAPEX and the number of spa visitors at 20% and 5,000 intervals respectively on the equity IRR. The results show that the geothermal spa will still not be viable at the assumed level of ticket sales even if CAPEX decreases by 40%. However, the spa will be moderately viable if the annual number of visitors increase to 35,000 and above even if CAPEX increases by 20%.

Table 19: Geothermal Spa CAPEX Scenarios

		CAPEX						
		$529,020	$705,360	$881,700	$1,058,040	$1,234,380	$1,410,720	$1,587,060
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
# of Visitors	5,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	10,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	15,000	-2.10%	-13.98%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	20,000	10.57%	1.54%	-4.75%	-13.06%	NEG IRR	NEG IRR	NEG IRR
	25,000	23.59%	10.79%	3.59%	-1.57%	-6.29%	-12.65%	NEG IRR
	30,000	39.79%	20.29%	10.92%	4.93%	0.45%	-3.26%	-7.24%
	35,000	57.91%	31.63%	18.41%	11.01%	5.88%	1.90%	-1.39%

✓ ***OPEX Scenarios***

Table 20 shows the impact of increases in OPEX and the number of spa visitors at 20% and 5,000 intervals respectively on the equity IRR. The results show that the equity IRR is less sensitive to changes in OPEX than CAPEX. The results show that the geothermal spa will still not be viable at the assumed level of ticket sales even if OPEX decreases by 40%. However, the spa will be moderately viable if the annual number of visitors increase to 35,000 and above even if OPEX increases by 20%.

Table 20: Geothermal Spa OPEX Scenarios

		OPEX						
		$89,169	$118,892	$148,615	$178,337	$208,060	$237,783	$267,506
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
# of Visitors	5,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	10,000	-15.01%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	15,000	-0.13%	-8.01%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	20,000	7.96%	2.03%	-4.75%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	25,000	15.74%	9.71%	3.59%	-3.10%	NEG IRR	NEG IRR	NEG IRR
	30,000	24.57%	17.33%	10.92%	4.61%	-2.20%	NEG IRR	NEG IRR
	35,000	34.79%	26.11%	18.41%	11.64%	5.10%	-1.93%	NEG IRR

✓ ***Price Scenarios***

Table 21 shows the impact of increases in the spa ticket price and the number of spa visitors at 20% and 5,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results show that the geothermal spa will still not be viable at the assumed level of ticket sales even if prices increase by up to 80%. However, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the spa will be viable if the annual number of visitors increase to 30,000 and above.

Table 21: Geothermal Spa Price Scenarios

		Price						
		$5.67	$7.57	$9.46	$11.35	$13.24	$15.13	$17.02
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
# of Visitors	5,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	10,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	-6.55%
	15,000	NEG IRR	NEG IRR	NEG IRR	-9.06%	-1.16%	4.28%	9.41%
	20,000	NEG IRR	NEG IRR	-4.75%	3.06%	9.92%	16.74%	24.48%
	25,000	NEG IRR	-6.84%	3.59%	12.07%	21.06%	31.68%	43.64%
	30,000	NEG IRR	0.56%	10.92%	21.66%	34.69%	49.43%	64.90%
	35,000	-8.22%	6.37%	18.41%	33.07%	50.21%	68.30%	86.67%

In summary, the geothermal spa is estimated to be unviable based on the current set of assumptions, especially the assumption that the spa will receive only 14,000 visitors per year, which is based on available information from the Olkaria geothermal spa in Kenya.[3] However, it is clear from the sensitivity analysis that the spa can be made viable by devising and implementing strategies to increase the number of tickets sold annually.

2.1.4 ***Direct Use Geothermal Project**: FRUIT DRYING (Greenfield)*
***Applicable Sites**: Hanle Garabbayis*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal fruit drying plant with a 1-ton/batch capacity is estimated at USD 275,470 (**Table 22**).

Table 22: Geothermal Fruit Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Construction	60,000
Batch Dryer	65,000
Land Acquisition Cost	-
Fruit peeling machine	3,500
Fruit Slicing Machine	1,500
Blanching machine	3,000
Pre-cooling machine	30,000
Packaging equipment	10,970
Total CAPEX ($ USD)	**275,470**

- ***Operating Costs***

The operating costs for the first year of the fruit drying plant operation are estimated at USD 255,578 (**Table 23**).

[3] Mangi, P., "Project Review of Geothermal Spa Construction in Kenya and Iceland," Kenya Electricity Generating Company Ltd. (KenGen), United Nations University Geothermal Training Programme, (2015): https://orkustofnun.is/gogn/unu-gtp-report/UNU-GTP-2015-21.pdf

Table 23: Geothermal Fruit Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Cost of Fresh Fruit (incl. Transport)	US$/Kg	0.67	168,464
Electricity Costs	US$/kwh	0.23	11,661
Equipment O&M	% of CAPEX	10.0%	27,547
Labor (Non-payroll)	US$/hr	0.82	21,096
Payroll	US$/Yr	N/A	18,127
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	1,591
Distribution/Marketing Expenses	% of Rev	0.5%	1,591
Utilities, Property Tax	US$/sqft	2.0	3,582
Packaging	US$/Kg	0.05	1,827
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**255,578**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal fruit drying to the cost of identified conventional fruit drying systems including open air sun drying, solar drying, and wood-fired systems. **Table 24** presents the results of the analysis showing the total annualized cost of each system.

Table 24: Fruit Drying Energy Systems Cost Comparison

	FRUIT DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	10.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	117	234	468	468
Max Annual Capacity per Dryer (Kg)	1,170.0	234,000.0	468,000.0	468,000.0
Volume of Fruit Processed per Year (Kg)	250,000	250,000	250,000	250,000
No. of Dryers Required	214.0	2.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$158,000.00	$226,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$12,840.00**	**$8,828.80**	**$7,900.00**	**$9,060.00**
Fuel Requirement (kg/Yr)	-	-	35,063.25	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.11	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$3,856.96**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.23	0.23
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$11,661.23**	**$11,661.23**
Annual Op Costs - Labour ($/Yr)	**$26,369.49**	**$21,095.59**	**$26,369.49**	**$21,095.59**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$6,420.00**	**$17,657.60**	**$15,800.00**	**$22,650.00**
Cost of Lost Revenue ($/Yr)	**$159,167.94**	-	-	-
Total Annualized Costs ($/Yr)	**$204,797.43**	**$47,581.99**	**$65,587.68**	**$64,466.83**
Total Annual Costs Savings ($/Yr)	**$140,330.60**	**-$16,884.83**	**$1,120.86**	
Total Annual Costs Savings (%)	**69%**	**-35%**	**2%**	

The analysis showed that solar drying has the least total annualized costs, followed by geothermal direct-use, wood-fired dryers and open-air sun drying. Switching to geothermal energy will result in costs savings of 2% and 69% compared to wood-fired dryers and open-air sun drying, respectively.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the fruit drying application, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is attractive with an after-tax equity IRR of 29.36%, payback period of 4 years and an after-tax project IRR of 19.72%. As shown in **Table 25**, the average annual revenue generated by the plant is USD 357,214, while the average total annual expenses are USD 288,734. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 1.06 million, while net cashflows to be distributed is USD 973,354. It is worth noting that the returns for this application are higher compared to the fish drying application mainly due to the lower cost of fresh fruits needed as input for the plant. Fresh fruit costs from Ethiopia were assumed for Djibouti.

Table 25: Geothermal Fruit Drying Analysis Results

FRUIT DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	39,089
Avg Annual Revenue	$357,214.26
Avg Annual Expenses	$288,734.14
Avg EBITDA	$68,480.12
Total CF to Equity	$1,055,995
Net CF to Equity	$973,354
Cash on Cash Return	11.78x
After Tax Equity IRR	29.36%
After Tax Project IRR	19.72%
Payback Year	4

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 26 shows the impact of increases in CAPEX and the quantity of fresh fruits processed at 20% and 50,000kg intervals, respectively, on the equity IRR. The results show that the geothermal fruit drying plant will not be viable at the base production level of 250,000kg if CAPEX increases by 60% and above.

Table 26: Geothermal Fruit Drying CAPEX Scenarios

		CAPEX						
		$165,282	$220,376	$275,470	$330,564	$385,658	$440,752	$495,846
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	150,000	10.24%	1.01%	-5.83%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	42.19%	21.48%	11.53%	5.35%	0.71%	-3.12%	-7.27%
	250,000	81.80%	48.11%	29.36%	18.67%	12.09%	7.44%	3.70%
	300,000	122.09%	77.92%	51.72%	35.07%	24.36%	17.32%	12.40%
	350,000	162.39%	108.12%	75.60%	54.14%	39.32%	28.99%	21.75%
	400,000	202.68%	138.35%	99.75%	74.06%	55.87%	42.59%	32.79%

  ✓ ***OPEX Scenarios***

Table 27 shows the impact of increases in OPEX and the quantity of fresh fruit processed at 20% and 50,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal fruit drying plant will not be viable at the base production level of 250,000kg if OPEX increases by 20% and above.

Table 27: Geothermal Fruit Drying OPEX Scenarios

		OPEX						
		$153,347	$204,463	$255,578	$306,694	$357,810	$408,926	$460,041
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	14.51%	-3.32%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	150,000	45.56%	17.57%	-5.83%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	82.60%	43.52%	11.53%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	120.19%	73.77%	29.36%	-4.61%	NEG IRR	NEG IRR	NEG IRR
	300,000	157.81%	104.62%	51.72%	8.13%	NEG IRR	NEG IRR	NEG IRR
	350,000	195.43%	135.52%	75.60%	19.91%	NEG IRR	NEG IRR	NEG IRR
	400,000	233.03%	166.42%	99.75%	34.31%	NEG IRR	NEG IRR	NEG IRR

✓ Price Scenarios

Table 28 shows the impact of increases in the price of dried fruits and the quantity of fresh fruits processed at 20% and 50,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results also reveal that the geothermal fruit drying plant will not be viable if prices decrease by 20% and above at the production levels analyzed except for the 20% price decrease at 400,000kg scenario. In addition, all the tables show that under the current base assumptions for CAPEX, OPEX and pricing, the plant will not be viable if the quantity of fresh fruit processed falls below 200,000kg.

Table 28: Geothermal Fruit Drying Price Scenarios

		Price						
		$4.85	$6.47	$8.09	$9.71	$11.33	$12.95	$14.56
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	NEG IRR	NEG IRR	NEG IRR	-7.11%	10.07%	26.31%	46.90%
	150,000	NEG IRR	NEG IRR	-5.83%	18.47%	48.10%	82.00%	116.32%
	200,000	NEG IRR	NEG IRR	11.53%	49.30%	94.69%	140.48%	186.27%
	250,000	NEG IRR	NEG IRR	29.36%	84.51%	141.75%	198.98%	256.18%
	300,000	NEG IRR	-2.76%	51.72%	120.12%	188.81%	257.46%	326.09%
	350,000	NEG IRR	6.32%	75.60%	155.74%	235.85%	315.93%	395.99%
	400,000	NEG IRR	14.61%	99.75%	191.35%	282.89%	374.39%	465.89%

In conclusion, the geothermal fruit drying plant is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that a slight increase in OPEX or decrease in prices will make the plant unviable.

2.2 ETHIOPIA

Geothermal Site	Categorized Direct Use Applications
Aluto-Langano	1. Fish drying 2. Greenhouse heating 3. Balneotherapy
Dubti	1. Vegetable/grain drying 2. Fruit drying 3. Fish drying
Abaya	1. Fish drying 2. Tobacco curing

2.2.1 ***Direct Use Geothermal Project:*** *BALNEOTHERAPY / GEOTHERMAL SPA (Greenfield)* ***Applicable Sites:*** *Aluto-Langano*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal spa with a 1,000-person/use capacity is estimated at USD 989,517 (**Table 29**).

Table 29: Geothermal Spa Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	10,500
Well Drilling & Pipes	565,000
Constr. Of Spa	286,200
Land Acquisition Cost	107,817
Total CAPEX ($ USD)	**989,517**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 123,557 (**Table 30**).

Table 30: Geothermal Spa Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Towel Supply and Laundry Costs	US$/Unit	3.38	3,380
Electricity Costs	US$/kwh	0.05	2,961
Equipment O&M	% of CAPEX	10.0%	98,952
Labor (Non-payroll)	US$/hr	0.26	6,066
Payroll	US$/Yr	N/A	6,487
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	657
Marketing Expenses	% of Rev	0.5%	657
Spa Building Utility Costs	US$/sqft	2.0	4,306
Opex Annual Inflator (%)		1%	
TOTAL OPEX			123,557

Cost Comparison

Balneotherapy is based on hot brine provided by geothermal resources only, hence, a cost comparison is not applicable.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the geothermal spa, based on the assumptions detailed in **Annex 1**, found that the project is unviable with a negative IRR as the cashflows projected to be generated over the life of the spa at the assumed level of ticket sales will be insufficient to pay back the initial investment. As shown in **Table 31**, the average annual revenue generated by the spa of USD 148,431 is only slightly higher than the projected average annual expenses of USD 139,586. The total loss to be incurred by investors over the life of the plant is estimated at USD 1.43 million.

Table 31: Geothermal Spa Analysis Results

GEOTHERMAL SPA RESULTS SUMMARY	
Avg Annual Sales (Tickets)	14,000
Avg Annual Revenue	$148,431.01
Avg Annual Expenses	$139,586.18
Avg EBITDA	$8,844.83
Total CF to Equity	-$1,132,816
Net CF to Equity	-$1,429,671
Cash on Cash Return	-4.82x
After Tax Equity IRR	-15.61%
After Tax Project IRR	-9.04%
Payback Year	#N/A

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 32 shows the impact of increases in CAPEX and the number of spa visitors at 20% and 5,000 intervals respectively on the equity IRR. The results show that the geothermal spa will still not be viable at the assumed level of ticket sales even if CAPEX decreases by 40%. However, the spa will be moderately viable if the annual number of visitors increase to 35,000 and above even if CAPEX increases by 20%.

Table 32: Geothermal Spa CAPEX Scenarios

		CAPEX						
		$593,710	$791,613	$989,517	$1,187,420	$1,385,323	$1,583,227	$1,781,130
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
# of Visitors	5,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	10,000	-9.87%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	15,000	4.38%	-3.28%	-10.95%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	20,000	15.53%	5.54%	-0.63%	-5.32%	-11.45%	NEG IRR	NEG IRR
	25,000	28.48%	13.87%	6.23%	1.03%	-2.95%	-6.71%	-11.74%
	30,000	44.15%	22.96%	12.90%	6.69%	2.19%	-1.33%	-4.34%
	35,000	61.13%	33.76%	19.89%	12.26%	7.02%	3.04%	-0.12%

- ✓ ***OPEX Scenarios***

Table 33 shows the impact of increases in OPEX and the number of spa visitors at 20% and 5,000 intervals respectively on the equity IRR. The results show that the equity IRR is less sensitive to changes in OPEX than CAPEX. The results show that the geothermal spa will still not be viable at the assumed level of ticket sales even if OPEX decreases by 40%. However, the spa will be moderately viable if the annual number of visitors increase to 35,000 and above even if OPEX increases by 40%.

Table 33: Geothermal Spa OPEX Scenarios

		OPEX						
		$74,134	$98,846	$123,557	$148,269	$172,980	$197,692	$222,403
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
# of Visitors	5,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	10,000	-9.22%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	15,000	0.24%	-3.97%	-10.95%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	20,000	7.20%	3.34%	-0.63%	-5.08%	-14.30%	NEG IRR	NEG IRR
	25,000	14.00%	10.17%	6.23%	2.28%	-1.85%	-7.08%	NEG IRR
	30,000	21.34%	16.94%	12.90%	8.96%	4.95%	0.89%	-3.49%
	35,000	29.82%	24.65%	19.89%	15.54%	11.53%	7.46%	3.36%

- ✓ ***Price Scenarios***

Table 34 shows the impact of increases in the spa ticket price and the number of spa visitors at 20% and 5,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results show that the geothermal spa will still not be viable at the assumed level of ticket sales even if prices increase by up to 80%. However, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the spa will be viable if the annual number of visitors increase to 30,000 and above.

Table 34: Geothermal Spa Price Scenarios

		Price						
		$5.67	$7.57	$9.46	$11.35	$13.24	$15.13	$17.02
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
# of Visitors	5,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	10,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	-14.87%	-7.01%	-3.08%
	15,000	NEG IRR	NEG IRR	-10.95%	-3.44%	1.16%	5.43%	9.67%
	20,000	NEG IRR	-8.25%	-0.63%	5.12%	10.76%	16.34%	22.55%
	25,000	-12.89%	-0.96%	6.23%	13.20%	20.58%	29.15%	38.82%
	30,000	-4.55%	4.51%	12.90%	21.84%	32.49%	44.52%	57.26%
	35,000	-0.11%	9.85%	19.89%	32.08%	46.15%	61.11%	76.35%

In conclusion, the geothermal spa is estimated to be unviable based on the current set of assumptions, especially the assumption that the spa will receive only 14,000 visitors a year based on available information from the Olkaria geothermal spa in Kenya.[4] However, it is clear from the sensitivity analysis that the spa can be made viable by devising and implementing strategies to increase the number of tickets sold annually.

2.2.2 ***Direct Use Geothermal Project:*** *GREENHOUSE HEATING (Retrofit)*
Applicable Sites: *Aluto-Langano*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of retrofitting a 5,000 sqm greenhouse to operate on geothermal heat is estimated at USD 458,500 (**Table 35**).

Table 35: Geothermal Greenhouse Retrofit Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	200,000
Pumps	3,500
Well Drilling	30,000
Pipes	225,000
Total CAPEX ($ USD)	**458,500**

- ***Operating Costs***

It is assumed that all the regular operating costs of the existing facility (except fuel costs which will be eliminated by the retrofit) will remain the same, while the annual O&M cost of the geothermal direct use system and retrofits is estimated at 10% of project CAPEX - $45,850.

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal greenhouse heating to the cost of identified conventional greenhouse heating systems, including fuel oil and liquified petroleum gas (LPG)-fueled systems. **Table 36** presents the results of the analysis showing the total annualized cost of each system.

[4] Mangi, P., "Project Review of Geothermal Spa Construction in Kenya and Iceland," Kenya Electricity Generating Company Ltd. (KenGen), United Nations University Geothermal Training Programme, (2015): https://orkustofnun.is/gogn/unu-gtp-report/UNU-GTP-2015-21.pdf

Table 36: Greenhouse Heating Systems Cost Comparison

	GREENHOUSE HEATING SYSTEMS COST COMPARISON		
	Fuel Oil	LPG	Geothermal
Total Heating Equipment Costs ($)	$40,000.00	$40,000.00	$458,500.00
Design Life - Heating Equipment (Yrs)	20	20	25
Annualized Capital Cost ($/Yr)	**$2,000.00**	**$2,000.00**	**$18,340.00**
Thermal Energy Requirement (MJ/Yr)	23,938,972.8	23,938,972.8	23,938,972.8
Calorific Value of Fuel (MJ/Kg)	41.5	46.3	-
Volume of Fuel Required (Kg/Yr)	576,842.7	517,040.4	-
Fuel Costs ($/Kg)	$0.54	$0.82	$0.00
Annual Op Costs - Fuel ($/Yr)	**$311,495.07**	**$423,973.17**	**$0.00**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$4,000.00**	**$4,000.00**	**$45,850.00**
Total Annualized Costs ($/Yr)	**$317,495.07**	**$429,973.17**	**$64,190.00**
Total Annual Costs Savings ($/Yr)	**$253,305.07**	**$365,783.17**	
Total Annual Costs Savings (%)	**80%**	**85%**	

The analysis found that geothermal direct use has the least total annualized costs, followed by fuel oil and LPG. Switching to geothermal energy will result in costs savings of 80% and 85% compared to fuel oil and LPG, respectively, mainly due to the avoided fuel expenditure. However, the sensitivity analysis presented below shows that with a major increase in the CAPEX to $2.3 million, the geothermal option becomes costlier than fuel oil by 1%.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the greenhouse retrofit project, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is very attractive with an after-tax equity IRR of 96.9%, payback period of 2 years and an after-tax project IRR of 42.4%. As shown in **Table 37**, the annual cost savings (compared to fuel oil) realized by the plant is USD 253,305. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 4.03 million, while net cashflows to be distributed is USD 3.9 million.

Table 37: Geothermal Greenhouse Retrofit Analysis Results

GREENHOUSE HEATING RESULTS SUMMARY	
Annual Cost Savings	$253,305.07
Total CF to Equity	$4,034,954
Net CF to Equity	$3,897,404
Cash on Cash Return	28.33x
After Tax Equity IRR	96.88%
After Tax Project IRR	42.42%
Payback Year	2

- ***Sensitivity Analysis***

Table 38 shows the impact of increases in CAPEX at 50% intervals on the equity IRR, payback period, and cost savings. The results reveal that the greenhouse retrofit will not be viable if CAPEX increases to $1.15 million at the greenhouse size analyzed.

Table 38: Geothermal Greenhouse Retrofit Sensitivity Analysis

		Equity IRR	Payback (Yrs)	Cost Savings ($/Yr)	Cost Savings (%)
CAPEX		96.88%	2	$253,305.07	80%
458,500	0%	96.88%	2	$253,305.07	80%
687,750	50%	43.24%	3	$221,210.07	70%
917,000	100%	20.00%	7	$189,115.07	60%
1,146,250	150%	9.42%	14	$157,020.07	49%
1,375,500	200%	2.65%	21	$124,925.07	39%
1,604,750	250%	-2.28%	NONE	$92,830.07	29%
1,834,000	300%	-6.84%	NONE	$60,735.07	19%
2,063,250	350%	-13.23%	NONE	$28,640.07	9%
2,292,500	400%	NEG IRR	NONE	-$3,454.93	-1%
2,521,750	450%	NEG IRR	NONE	-$35,549.93	-11%
2,751,000	500%	NEG IRR	NONE	-$67,644.93	-21%

In summary, the greenhouse retrofit project is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that a major increase in CAPEX will make the project unviable, although it is also worth noting that the cost savings to be realized could be much higher than the values depicted herein depending on the fuel type.

2.2.3 ***Direct Use Geothermal Project***: *VEGETALBE/GRAIN DRYING (Greenfield)* ***Applicable Sites:*** *Dubti*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal vegetable drying plant with a 1-ton/batch capacity is estimated at USD 290,686 (**Table 39**).

Table 39: Geothermal Vegetable Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Construction	60,000
Batch Dryer	65,000
Land Acquisition Cost	20,215.63
Blanching machine	3,000
Pre-cooling machine	30,000
Packaging equipment	10,970
Total CAPEX ($ USD)	**290,686**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 245,398 (**Table 40**).

Table 40: Geothermal Vegetable Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Cost of Fresh Veg (incl. Transport)	US$/Kg	0.32	177,898
Electricity Costs	US$/kwh	0.05	5,500
Equipment O&M	% of CAPEX	10.0%	29,069
Labor (Non-payroll)	US$/hr	0.26	5,377
Payroll	US$/Yr	N/A	6,487
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	1,451
Distribution/Marketing Expenses	% of Rev	0.5%	1,451
Utilities, Property Tax	US$/sqft	2.0	10,764
Packaging	US$/Kg	0.09	7,309
Opex Annual Inflator (%)		1%	
TOTAL OPEX			245,398

Cost Comparison

A cost comparison analysis was conducted to compare the cost of a geothermal vegetable drying plant to the cost of identified conventional vegetable drying systems including open air sun drying, solar drying and wood-fired drying systems. **Table 41** presents the results of the analysis showing the total annualized cost of each system.

Table 41: Vegetable Drying Energy Systems Cost Comparison

	VEGETABLE DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	5.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	300	600	600	600
Max Annual Capacity per Dryer (Kg)	1,500.0	600,000.0	600,000.0	600,000.0
Volume of Veg Processed per Year (Kg)	550,000	550,000	550,000	550,000
No. of Dryers Required	367.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$158,000.00	$226,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$22,020.00**	**$4,414.40**	**$7,900.00**	**$9,060.00**
Fuel Requirement (kg/Yr)	-	-	79,019.35	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.10	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$7,901.93**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.05	0.05
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$5,500.00**	**$5,500.00**
Annual Op Costs - Labour ($/Yr)	**$6,721.70**	**$5,377.36**	**$6,721.70**	**$5,377.36**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$11,010.00**	**$8,828.80**	**$15,800.00**	**$22,650.00**
Cost of Lost Revenue ($/Yr)	**$145,109.25**	-	-	-
Total Annualized Costs ($/Yr)	**$184,860.95**	**$18,620.56**	**$43,823.63**	**$42,587.36**
Total Annual Costs Savings ($/Yr)	**$142,273.59**	**-$23,966.80**	**$1,236.27**	
Total Annual Costs Savings (%)	**77%**	**-129%**	**3%**	

The analysis found that solar drying has the least total annualized costs, followed by geothermal direct-use, wood-fired dryers and open-air sun drying. Switching to geothermal energy will result in costs savings of 3% and 77% compared to wood-fired dryers and open-air sun drying, respectively.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the vegetable drying application, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is moderate with an after-tax equity IRR of 12.86%, payback period of 12 years and an after-tax project IRR of 13.59%. As shown in **Table 42**, the average annual revenue generated by the plant is USD 325,811, while average total annual expenses are USD 277,233. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 597,851, while net cashflows to be distributed is USD 510,646.

Table 42: Geothermal Vegetable Drying Analysis Results

VEGETABLE DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	78,178
Avg Annual Revenue	$325,810.56
Avg Annual Expenses	$277,232.99
Avg EBITDA	$48,577.57
Total CF to Equity	$597,851
Net CF to Equity	$510,646
Cash on Cash Return	5.86x
After Tax Equity IRR	12.86%
After Tax Project IRR	13.59%
Payback Year	12

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 43 shows the impact of increases in CAPEX and the quantity of fresh vegetables processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the geothermal vegetable drying plant will not be viable if CAPEX increases by 20% and above at the production levels analyzed, except for the 600,000kg volume and 20% CAPEX increase scenario.

Table 43: Geothermal Vegetable Drying CAPEX Scenarios

		CAPEX						
		$174,411	$232,549	$290,686	$348,823	$406,960	$465,097	$523,234
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	0.24%	-8.38%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	350,000	8.02%	-0.50%	-6.86%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	400,000	15.57%	5.37%	-0.95%	-5.95%	-12.97%	NEG IRR	NEG IRR
	450,000	24.09%	11.09%	3.78%	-1.26%	-5.35%	-10.81%	NEG IRR
	500,000	33.99%	16.78%	8.38%	2.72%	-1.47%	-4.99%	-9.45%
	550,000	44.90%	23.19%	12.86%	6.56%	1.96%	-1.64%	-4.73%
	600,000	56.34%	30.38%	17.52%	10.37%	5.26%	1.39%	-1.76%

  ✓ ***OPEX Scenarios***

Table 44 shows the impact of increases in OPEX and the quantity of fresh vegetable processed at 20% and 50,000kg intervals, respectively, on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal vegetable drying plant will not be viable if OPEX increases by 20% and above at the production levels analyzed.

Table 44: Geothermal Vegetable Drying OPEX Scenarios

		OPEX						
		$147,239	$196,318	$245,398	$294,478	$343,557	$392,637	$441,716
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	23.82%	6.68%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	350,000	34.44%	12.98%	-6.86%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	400,000	46.24%	19.61%	-0.95%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	450,000	58.62%	27.21%	3.78%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	500,000	71.23%	35.74%	8.38%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	550,000	83.92%	44.93%	12.86%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	600,000	96.64%	54.50%	17.52%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 45 shows the impact of increases in the price of dried vegetables and the quantity of fresh vegetables processed at 20% and 50,000kg intervals, respectively, on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results also reveal that the geothermal vegetable drying plant will not be viable if prices decrease by 20% and above at the production levels analyzed. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable if the quantity of fresh vegetables processed falls below 550,000kg.

Table 45: Geothermal Vegetable Drying Price Scenarios

		Price						
		$2.21	$2.95	$3.69	$4.43	$5.17	$5.90	$6.64
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	NEG IRR	NEG IRR	NEG IRR	6.54%	23.57%	45.76%	70.51%
	350,000	NEG IRR	NEG IRR	-6.86%	13.72%	36.64%	65.00%	94.34%
	400,000	NEG IRR	NEG IRR	-0.95%	21.48%	51.26%	84.59%	118.21%
	450,000	NEG IRR	NEG IRR	3.78%	30.51%	66.49%	104.26%	142.08%
	500,000	NEG IRR	NEG IRR	8.38%	40.63%	81.90%	123.93%	165.93%
	550,000	NEG IRR	NEG IRR	12.86%	51.40%	97.36%	143.59%	189.78%
	600,000	NEG IRR	NEG IRR	17.52%	62.47%	112.83%	163.24%	213.62%

In conclusion, the geothermal vegetable drying plant is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that a slight increase in CAPEX/OPEX or decrease in prices will make the plant unviable. In addition, the projected investor returns are moderate and could be made more attractive by maximizing the capacity of the plant with two full daily batches to process 600,000kg annually, thereby realizing economies of scale. The project would also generate more attractive returns if it were supported by concessional funding with much lower interest rates than the 14.5% assumed.

2.2.4 ***Direct Use Geothermal Project****: FRUIT DRYING (Greenfield)*
Applicable Sites*: Dubti*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal fruit drying plant with a 1-ton/batch capacity is estimated at USD 288,947 (**Table 46**).

Table 46: Geothermal Fruit Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Construction	60,000
Batch Dryer	65,000
Land Acquisition Cost	13,477.09
Fruit peeling machine	3,500
Fruit Slicing Machine	1,500
Blanching machine	3,000
Pre-cooling machine	30,000
Packaging equipment	10,970
Total CAPEX ($ USD)	**288,947**

- ***Operating Costs***

The operating costs for the first year of the fruit drying plant operation are estimated at USD 221,620 (**Table 47**).

Table 47: Geothermal Fruit Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	*Units*	Cost/Unit	1st Year (USD)
Cost of Fresh Fruit (incl. Transport)	US$/Kg	0.67	168,464
Electricity Costs	US$/kwh	0.05	2,500
Equipment O&M	% of CAPEX	10.0%	28,895
Labor (Non-payroll)	US$/hr	0.26	6,591
Payroll	US$/Yr	N/A	6,487
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	1,591
Distribution/Marketing Expenses	% of Rev	0.5%	1,591
Utilities, Property Tax	US$/sqft	2.0	3,582
Packaging	US$/Kg	0.05	1,827
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**221,620**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal fruit drying to the cost of identified conventional fruit drying systems including open-air sun drying, solar drying, and wood-fired systems. **Table 48** presents the results of the analysis showing the total annualized cost of each system.

Table 48: Fruit Drying Energy Systems Cost Comparison

	FRUIT DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	10.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	117	234	468	468
Max Annual Capacity per Dryer (Kg)	1,170.0	234,000.0	468,000.0	468,000.0
Volume of Fruit Processed per Year (Kg)	250,000	250,000	250,000	250,000
No. of Dryers Required	214.0	2.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$158,000.00	$226,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$12,840.00**	**$8,828.80**	**$7,900.00**	**$9,060.00**
Fuel Requirement (kg/Yr)			35,063.25	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.07	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$2,384.30**	**$0.00**
Electricity Requirement (kWh/Kg)			0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.05	0.05
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$2,500.00**	**$2,500.00**
Annual Op Costs - Labour ($/Yr)	**$8,238.88**	**$6,591.11**	**$8,238.88**	**$6,591.11**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$6,420.00**	**$17,657.60**	**$15,800.00**	**$22,650.00**
Cost of Lost Revenue ($/Yr)	**$159,167.94**			-
Total Annualized Costs ($/Yr)	**$186,666.82**	**$33,077.51**	**$36,823.18**	**$40,801.11**
Total Annual Costs Savings ($/Yr)	**$145,865.71**	**-$7,723.60**	**-$3,977.92**	
Total Annual Costs Savings (%)	**78%**	**-23%**	**-11%**	

The analysis found that solar drying has the least total annualized costs, followed by wood-fired dryers, geothermal direct-use and open-air sun drying. Wood-fired dryers have a lower annualized cost compared to geothermal heating due to the assumed low cost at $0.07 per kg. However, geothermal energy will be cheaper with any slight increase in the cost of firewood from the base value assumed. Also, switching to geothermal energy will result in costs savings of 78% compared to open-air sun drying.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the fruit drying application, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is attractive with an after-tax equity IRR of 47.42%, payback period of 3 years and an after-tax project IRR of 27.52%. As shown in **Table 49**, the average annual revenue generated by the plant is USD 357,214, while the average total annual expenses are USD 250,371. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 1.62 million, while net cashflows to be distributed is USD 1.53 million. It is worth noting that the returns for this application are higher compared to the fish drying application mainly due to the lower cost of fresh fruits needed as input for the plant.

Table 49: Geothermal Fruit Drying Analysis Results

FRUIT DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	39,089
Avg Annual Revenue	$357,214.26
Avg Annual Expenses	$251,449.41
Avg EBITDA	$105,764.85
Total CF to Equity	$1,600,138
Net CF to Equity	$1,513,453
Cash on Cash Return	17.46x
After Tax Equity IRR	46.67%
After Tax Project IRR	27.28%
Payback Year	3

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 50 shows the impact of increases in CAPEX and the quantity of fresh fruits processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the geothermal fruit drying plant will remain viable at the base production level of 250,000kg even if CAPEX increases by 80%.

Table 50: Geothermal Fruit Drying CAPEX Scenarios

		CAPEX						
		$173,368	$231,158	$288,947	$346,737	$404,526	$462,315	$520,105
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	9.64%	0.85%	-5.03%	-12.79%	NEG IRR	NEG IRR	NEG IRR
	150,000	38.86%	19.67%	10.56%	4.59%	0.27%	-3.23%	-6.67%
	200,000	76.31%	44.17%	26.68%	16.94%	10.95%	6.44%	2.92%
	250,000	114.66%	72.39%	47.42%	31.82%	22.02%	15.64%	11.17%
	300,000	153.02%	101.13%	70.04%	49.60%	35.68%	26.16%	19.59%
	350,000	191.34%	129.91%	93.02%	68.48%	51.17%	38.66%	29.58%
	400,000	229.65%	158.66%	116.04%	87.61%	67.36%	52.35%	41.02%

✓ ***OPEX Scenarios***

Table 51 shows the impact of increases in OPEX and the quantity of fresh fruit processed at 20% and 50,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal fruit drying plant will not be viable at the base production level of 250,000kg if OPEX increases by 40% and above.

Table 51: Geothermal Fruit Drying OPEX Scenarios

		OPEX						
		$132,972	$177,296	$221,620	$265,944	$310,268	$354,593	$398,917
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	20.32%	7.94%	-5.03%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	150,000	50.35%	27.96%	10.56%	-7.12%	NEG IRR	NEG IRR	NEG IRR
	200,000	84.40%	54.43%	26.68%	5.74%	NEG IRR	NEG IRR	NEG IRR
	250,000	118.79%	82.91%	47.42%	16.94%	-10.32%	NEG IRR	NEG IRR
	300,000	153.18%	111.61%	70.04%	30.27%	0.72%	NEG IRR	NEG IRR
	350,000	187.56%	140.32%	93.02%	46.13%	8.44%	NEG IRR	NEG IRR
	400,000	221.92%	169.01%	116.04%	63.07%	15.95%	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 52 shows the impact of increases in the price of dried fruits and the quantity of fresh fruits processed at 20% and 50,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results also reveal that the geothermal fruit drying plant will not be viable if prices decrease by 20% and above at the base case production level. In addition, all the tables show that under the current base assumptions for CAPEX, OPEX and pricing, the plant will not be viable if the quantity of fresh fruit processed falls below 150,000kg.

Table 52: Geothermal Fruit Drying Price Scenarios

		Price						
		$4.85	$6.47	$8.09	$9.71	$11.33	$12.95	$14.56
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	NEG IRR	NEG IRR	-5.03%	8.94%	22.65%	40.06%	59.72%
	150,000	NEG IRR	NEG IRR	10.56%	33.15%	62.29%	92.78%	123.37%
	200,000	NEG IRR	-1.30%	26.68%	64.87%	105.59%	146.37%	187.13%
	250,000	NEG IRR	7.20%	47.42%	98.00%	148.99%	199.92%	250.84%
	300,000	NEG IRR	15.40%	70.04%	131.21%	192.35%	253.45%	314.53%
	350,000	NEG IRR	24.68%	93.02%	164.40%	235.70%	306.97%	378.21%
	400,000	NEG IRR	35.58%	116.04%	197.58%	279.04%	360.47%	441.89%

In summary, the geothermal fruit drying plant is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that a slight increase in OPEX or decrease in prices will make the plant unviable.

2.2.5 ***Direct Use Geothermal Project:*** *FISH DRYING (Greenfield)* ***Applicable Sites:*** *Aluto-Langano, Dubti, Abaya*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal fish drying plant with a 1-ton/batch capacity is estimated at USD 277,947 (**Table 53**).

Table 53: Geothermal Fish Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Constr. Of Drying Station	150,000
Drying Cabinet	2,000
Packaging equipment	10,970
Land Acquisition Cost	13,477.09
Total CAPEX ($ USD)	**277,947**

- ***Operating Costs***

The operating costs for the first year of plant operation is estimated at USD 863,571 (**Table 54**). The cost of fresh fish is assumed to be ETB 100/kg.[5]

[5] Information based on local stakeholder interviews.

Table 54: Geothermal Fish Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Cost of Fresh Fish (incl. Transport)	US$/Kg	2.70	808,625
Electricity Costs	US$/kwh	0.05	3,000
Equipment O&M	% of CAPEX	10.0%	27,795
Labor (Non-payroll)	US$/hr	0.26	4,609
Payroll	US$/Yr	N/A	6,487
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	3,157
Distribution/Marketing Expenses	% of Rev	0.5%	3,157
Utilities, Property Tax	US$/sqft	2.0	3,582
Packaging	US$/Kg	0.05	3,067
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**863,571**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal fish drying to the cost of identified conventional fish drying systems including open-air sun drying, solar drying, and wood-fired systems. **Table 55** presents the results of the analysis showing the total annualized cost of each system.

Table 55: Fish Drying Energy Systems Cost Comparison

	FISH DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	10.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	150	300	300	300
Max Annual Capacity per Dryer (Kg)	1,500.0	300,000.0	300,000.0	300,000.0
Volume of Fish Processed per Year (Kg)	300,000	300,000	300,000	300,000
No. of Dryers Required	200.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$185,000.00	$253,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$12,000.00**	**$4,414.40**	**$9,250.00**	**$10,140.00**
Fuel Requirement (kg/Yr)	-	-	39,135.66	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.07	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$2,661.22**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.05	0.05
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$3,000.00**	**$3,000.00**
Annual Op Costs - Labour ($/Yr)	**$5,761.46**	**$4,609.16**	**$5,761.46**	**$4,609.16**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$6,000.00**	**$8,828.80**	**$18,500.00**	**$25,350.00**
Cost of Lost Revenue ($/Yr)	**$285,450.00**	-	-	-
Total Annualized Costs ($/Yr)	**$309,211.46**	**$17,852.36**	**$39,172.68**	**$43,099.16**
Total Annual Costs Savings ($/Yr)	**$266,112.29**	**-$25,246.80**	**-$3,926.48**	
Total Annual Costs Savings (%)	**86%**	**-141%**	**-10%**	

The analysis found that solar drying has the least total annualized costs, followed by wood-fired dryers, geothermal direct-use and open-air sun drying. Wood-fired dryers have a lower annualized cost compared to geothermal heating due to the assumed low cost at $0.07 per kg. However, geothermal energy will be cheaper with any slight increase in the cost of firewood from the base value assumed. Also, switching to geothermal energy will result in costs savings of 86% compared to open-air sun drying.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the fish drying application, based on the assumptions detailed in **Annex 1**, found that the project is unviable with a negative IRR, as the cashflows projected to be generated over the life of the plant at the assumed level of production will be insufficient to pay back the initial investment. As shown in **Table 56**, the average annual revenue generated by the plant of USD 708,806 is much less than the projected average annual expenses of USD 975,601. The total loss to be incurred by investors over the life of the plant is estimated at USD 7.13 million.

Table 56: Geothermal Fish Drying Analysis Results

FISH DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	65,604
Avg Annual Revenue	$708,806
Avg Annual Expenses	$975,601
Avg EBITDA	#DIV/0!
Total CF to Equity	-$7,050,176
Net CF to Equity	-$7,133,561
Cash on Cash Return	-85.55x
After Tax Equity IRR	NEG IRR
After Tax Project IRR	#NUM!
Payback Year	#N/A

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 57 shows the impact of increases in CAPEX and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the geothermal fish drying plant will not be viable under any of the scenarios considered.

Table 57: Geothermal Fish Drying CAPEX Scenarios

		CAPEX						
		$166,768	$222,358	$277,947	$333,537	$389,126	$444,715	$500,305
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	225,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	275,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	300,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR

  ✓ ***OPEX Scenarios***

Table 58 shows the impact of increases in OPEX and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal fish drying plant will be viable if OPEX decreases by 40%.

Table 58: Geothermal Fish Drying OPEX Scenarios

		OPEX						
		$518,143	$690,857	$863,571	$1,036,286	$1,209,000	$1,381,714	$1,554,428
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	14.68%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	21.19%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	28.60%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	225,000	36.83%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	45.62%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	275,000	54.72%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	300,000	63.98%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 59 shows the impact of increases in the price of dry fish and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX. The results also reveal that the geothermal fish drying plant will be viable if prices increase by 60%. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable at the production levels analyzed.

Table 59: Geothermal Fish Drying Price Scenarios

		Price						
		$5.74	$7.65	$9.57	$11.48	$13.39	$15.31	$17.22
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	18.98%	66.97%
	175,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	28.66%	88.11%
	200,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	39.75%	109.30%
	225,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	51.65%	130.49%
	250,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	-16.26%	63.90%	151.68%
	275,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	-7.99%	76.28%	172.85%
	300,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	-3.83%	88.71%	194.01%

In summary, the geothermal fish drying plant is estimated to be unviable based on the current assumptions especially due to the high cost of fresh fish. However, it is clear from the sensitivity analysis that the project can be made viable by exploring opportunities to decrease OPEX and/or increase prices.

2.2.6 ***Direct Use Geothermal Project:*** *TOBACCO CURING (Retrofit)* ***Applicable Sites:*** *Abaya*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of retrofitting a tobacco curing plant producing 750 tons of cured tobacco per year to operate on geothermal heat is estimated at USD 488,500 (**Table 60**).

Table 60: Tobacco Curing Plant Retrofit Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	360,000
Pumps	3,500
Well Drilling	30,000
Pipes	45,000
Electrical Retrofitting	50,000
Total CAPEX ($ USD)	**488,500**

- ***Operating Costs***

It is assumed that all the regular operating costs of the existing facility (except fuel costs which will be eliminated by the retrofit and reduced labor costs) will remain the same, while the annual O&M cost of the geothermal direct-use system and retrofits is estimated at 10% of project CAPEX - $17,850.

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal tobacco curing to the cost of identified conventional tobacco curing systems including diesel-fired electrical barns and wood-fired barns.[6] **Table 61** presents the results of the analysis showing the total annualized cost of each system.

Table 61: Tobacco Curing Energy Systems Cost Comparison

	TOBACCO CURING ENERGY SYSTEMS COST COMPARISON		
	Diesel	Wood	Geothermal
Total Heating Equipment Costs ($)	$90,000.00	$103,500.00	$488,500.00
Design Life - Heating Equipment (Yrs)	20	20	25
Output per Batch per Barn (Kg)	1,200.0	1,200.0	1,200.0
No. of Batches per Year per Barn	36.4	36.4	36.4
Annual Output per Barn (Kg)	43,680.0	43,680.0	43,680.0
Volume of Cured Tobacco per Year (Kg)	756,905	756,905	756,905
No. of Barns Required	18.0	18.0	18.0
Annualized Capital Cost ($/Yr)	**$4,500.00**	**$5,175.00**	**$19,540.00**
Fuel Requirement (Ltr. or m3/Kg)	0.5	0.01	-
Fuel Costs ($/Ltr. or m3)	$0.62	$40.43	$0.00
Annual Op Costs - Fuel ($/Yr)	**$234,620.07**	**$306,026.18**	**$0.00**
Electricity Requirement (kWh/Kg)	0.88	-	0.88
Electricity Cost ($/kWh)	$0.05	$0.05	$0.05
Annual Op Costs - Electricity ($/Yr)	**$33,114.58**	**$0.00**	**$33,114.58**
Plant Labor Required per Barn	0.33	0.47	0.33
Total Plant Labor Required	6.00	8.40	6.00
Labor Costs ($/hr)	$0.26	$0.26	$0.26
No. of Curing Days per Year	212.33	212.33	212.33
Annual Op Costs - Labour ($/Yr)	**$7,829.43**	**$10,961.21**	**$7,829.43**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$9,000.00**	**$10,350.00**	**$48,850.00**
Cost of Lost Revenue ($/Yr)	-	-	-
Other Costs ($/Yr)	-	-	-
Total Annualized Costs ($/Yr)	**$289,064.09**	**$332,512.39**	**$109,334.02**
Total Annual Costs Savings ($/Yr)	**$179,730.07**	**$223,178.37**	
Total Annual Costs Savings (%)	**62%**	**67%**	

[6] Information based on local stakeholder interviews.

The analysis found that geothermal direct use has the least total annualized costs, followed by diesel and wood fuel, mainly due to the avoided fuel expenditure.[7] However, it is important to note that the results could be very different with a major increase in the CAPEX for the geothermal option as shown in the sensitivity analysis below. It should be noted that the cost savings represent savings to be realized from retrofitting the existing plant which utilizes both diesel and wood.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the tobacco curing retrofit project, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is very attractive with an after-tax equity IRR of 59.32%, payback period of 2 years and an after-tax project IRR of 30.96%. As shown in **Table 62**, the annual cost savings realized by the plant is USD 191,453. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 2.93 million while net cashflows to be distributed is USD 2.78 million.

Table 62: Geothermal Tobacco Curing Analysis Results

TOBACCO CURING RESULTS SUMMARY	
Annual Cost Savings	$191,453.10
Total CF to Equity	$2,926,510
Net CF to Equity	$2,779,960
Cash on Cash Return	18.97x
After Tax Equity IRR	59.32%
After Tax Project IRR	30.96%
Payback Year	2

- ***Sensitivity Analysis***

Table 63 shows the impact of increases in CAPEX at 40% intervals on the equity IRR, payback period, and cost savings. The results reveal that the tobacco curing plant retrofit will not be viable if CAPEX increases up to USD 1 million and above at the production levels analyzed.

Table 63: Geothermal Tobacco Curing Plant Retrofit Sensitivity Analysis

		Equity IRR	Payback (Yrs)	Cost Savings ($/Yr)	Cost Savings (%)
CAPEX		59.32%	2	$191,453.10	65%
293,100	-40%	142.34%	1	$218,809.10	75%
488,500	0%	59.32%	2	$191,453.10	65%
683,900	40%	26.10%	5	$164,097.10	56%
879,300	80%	12.05%	13	$136,741.10	47%
1,074,700	120%	4.25%	19	$109,385.10	37%
1,270,100	160%	-1.25%	NONE	$82,029.10	28%
1,465,500	200%	-5.83%	NONE	$54,673.10	19%
1,660,900	240%	-12.09%	NONE	$27,317.10	9%
1,856,300	280%	NEG IRR	NONE	-$38.90	0%
2,051,700	320%	NEG IRR	NONE	-$27,394.90	-9%
2,247,100	360%	NEG IRR	NONE	-$54,750.90	-19%

In conclusion, the geothermal tobacco curing plant retrofit project is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that increases in CAPEX will result in lower cost savings which would render the retrofit unviable.

[7] Fuel costs accounted for over 80% of the annualized costs for the diesel and wood-fired systems.

2.3 KENYA

Geothermal Site	Categorized Direct Use Applications
Olkaria	1. Fish drying 2. Chicken hatchery
Eburru	1. Pyrethrum drying 2. Fruit drying
Menengai	1. Vegetable drying 2. Greenhouse

2.3.1 ***Direct Use Geothermal Project:*** *FISH DRYING (Greenfield)* ***Applicable Sites:*** *Olkaria*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal fish drying plant with a 1-ton/batch capacity is estimated at USD 269,029 (**Table 64**).

Table 64: Geothermal Fish Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Constr. Of Drying Station	150,000
Drying Cabinet	2,000
Packaging equipment	10,970
Land Acquisition Cost	4,559.01
Total CAPEX ($ USD)	**269,029**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 529,676 (**Table 65**). The cost of fresh fish is based on figures from Rwanda.

Table 65: Geothermal Fish Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Cost of Fresh Fish (incl. Transport)	US$/Kg	1.50	450,000
Electricity Costs	US$/kwh	0.14	8,634
Equipment O&M	% of CAPEX	10.0%	26,903
Labor (Non-payroll)	US$/hr	0.77	13,945
Payroll	US$/Yr	N/A	17,745
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	2,854
Distribution/Marketing Expenses	% of Rev	0.5%	2,854
Utilities, Property Tax	US$/sqft	2.0	3,582
Packaging	US$/Kg	0.05	3,067
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**529,676**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal fish drying to the cost of identified conventional fish drying systems including open air sun drying, solar drying, and wood-fired systems. **Table 66** presents the result of the analysis showing the total annualized cost of each system.

Table 66: Fish Drying Energy Systems Cost Comparison

	FISH DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	10.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	150	300	300	300
Max Annual Capacity per Dryer (Kg)	1,500.0	300,000.0	300,000.0	300,000.0
Volume of Fish Processed per Year (Kg)	300,000	300,000	300,000	300,000
No. of Dryers Required	200.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$185,000.00	$253,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$12,000.00**	**$4,414.40**	**$9,250.00**	**$10,140.00**
Fuel Requirement (kg/Yr)	-	-	39,135.66	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.07	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$2,543.82**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.14	0.14
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$8,634.46**	**$8,634.46**
Annual Op Costs - Labour ($/Yr)	**$17,431.84**	**$13,945.48**	**$17,431.84**	**$13,945.48**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$6,000.00**	**$8,828.80**	**$18,500.00**	**$25,350.00**
Cost of Lost Revenue ($/Yr)	$285,450.00	-	-	-
Total Annualized Costs ($/Yr)	**$320,881.84**	**$27,188.68**	**$56,360.12**	**$58,069.93**
Total Annual Costs Savings ($/Yr)	**$262,811.91**	**-$30,881.26**	**-$1,709.81**	
Total Annual Costs Savings (%)	**82%**	**-114%**	**-3%**	

The analysis found that solar drying has the least total annualized costs, followed by wood-fired dryers, geothermal direct-use and open-air sun drying. Wood-fired dryers have a lower annualized cost compared to geothermal heating due to the assumed low cost at $0.07 per kg. However, geothermal energy will be cheaper with any slight increase in the cost of firewood from the base value assumed. Switching to geothermal energy will also result in cost savings of 82% compared to open-air sun drying.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the fish drying application, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is moderate with an after-tax equity IRR of 14.12%, payback period of 12 years and an after-tax project IRR of 13.16%. As shown in **Table 67**, the average annual revenue generated by the plant is USD 640,738, while the average total annual expenses are USD 598,390. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 564,582, while net cashflows to be distributed is USD 483,874.

Table 67: Geothermal Fish Drying Analysis Results

FISH DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	65,604
Avg Annual Revenue	$640,738
Avg Annual Expenses	$598,390
Avg EBITDA	$42,348
Total CF to Equity	$564,582
Net CF to Equity	$483,874
Cash on Cash Return	6.00x
After Tax Equity IRR	14.12%
After Tax Project IRR	13.16%
Payback Year	12

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 68 shows the impact of increases in CAPEX and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the geothermal fish drying plant will not be viable if CAPEX increases by 20% and above at the production levels analyzed.

Table 68: Geothermal Fish Drying CAPEX Scenarios

		CAPEX						
		$161,417	$215,223	$269,029	$322,835	$376,641	$430,446	$484,252
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	-2.68%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	5.27%	-3.56%	-15.01%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	12.50%	2.59%	-4.13%	-12.91%	NEG IRR	NEG IRR	NEG IRR
	225,000	20.26%	8.15%	0.96%	-4.54%	-11.71%	NEG IRR	NEG IRR
	250,000	29.19%	13.51%	5.48%	-0.15%	-4.85%	-10.93%	NEG IRR
	275,000	39.16%	19.31%	9.82%	3.69%	-0.96%	-5.09%	-10.37%
	300,000	49.77%	25.77%	14.12%	7.37%	2.39%	-1.57%	-5.28%

  ✓ ***OPEX Scenarios***

Table 69 shows the impact of increases in OPEX and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal fish drying plant will not be viable if OPEX increases by 20% and above at the production levels analyzed.

Table 69: Geothermal Fish Drying OPEX Scenarios

		OPEX						
		$317,806	$423,741	$529,676	$635,611	$741,547	$847,482	$953,417
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	74.89%	24.57%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	96.53%	36.68%	-15.01%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	118.21%	50.03%	-4.13%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	225,000	139.89%	63.92%	0.96%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	161.57%	78.01%	5.48%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	275,000	183.25%	92.15%	9.82%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	300,000	204.93%	106.32%	14.12%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 70 shows the impact of increases in the price of dry fish and the quantity of fresh fish processed at 20% and 25,000 intervals, respectively, on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results also reveal that the geothermal fish drying plant will not be viable if prices decrease by 20% and above at the production levels analyzed. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable if the quantity of fresh fish processed falls below 300,000kg.

Table 70: Geothermal Fish Drying Price Scenarios

		Price						
		$5.19	$6.92	$8.65	$10.38	$12.11	$13.84	$15.57
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	NEG IRR	NEG IRR	NEG IRR	23.79%	73.07%	125.62%	178.19%
	175,000	NEG IRR	NEG IRR	-15.01%	36.93%	97.20%	158.55%	219.86%
	200,000	NEG IRR	NEG IRR	-4.13%	51.53%	121.37%	191.47%	261.52%
	225,000	NEG IRR	NEG IRR	0.96%	66.69%	145.54%	224.38%	303.18%
	250,000	NEG IRR	NEG IRR	5.48%	82.04%	169.71%	257.29%	344.83%
	275,000	NEG IRR	NEG IRR	9.82%	97.44%	193.87%	290.20%	386.49%
	300,000	NEG IRR	NEG IRR	14.12%	112.86%	218.03%	323.10%	428.14%

In summary, the geothermal fish drying plant is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that a slight increase in CAPEX/OPEX or decrease in prices will make the plant unviable.

2.3.2 ***Direct Use Geothermal Project:*** *CHICKEN HATHERY (Retrofit)*
Applicable Sites: *Olkaria*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of retrofitting a chicken hatchery with a 100,000 egg/batch total capacity to operate on geothermal heat is estimated at USD 98,500 (**Table 71**).

Table 71: Geothermal Chicken Hatchery Retrofit Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Pipes	45,000
Total CAPEX ($ USD)	**98,500**

- ***Operating Costs***

It is assumed that all the regular operating costs of the existing facility (except fuel costs which will be eliminated by the retrofit) will remain the same, while the annual O&M cost of the geothermal direct use system and retrofits is estimated at 10% of project CAPEX – USD 9,850.

Cost Comparison

A cost comparison analysis was conducted to compare the cost of a geothermal chicken hatchery to the cost of identified conventional chicken hatchery heating systems including fuel oil, electric steam and gas-fired hatcheries. **Table 72** presents the results of the analysis showing the total annualized cost of each system.

Table 72: Chicken Hatchery Heating Systems Cost Comparison

	CHICKEN HATCHERIES HEATING SYSTEMS COST COMPARISON			
	Fuel Oil	Electric	Gas	Geothermal
Total Heating Equipment Costs ($)	$30,000.00	$30,000.00	$30,000.00	$98,500.00
Design Life - Heating Equipment (Yrs)	20	20	20	25
Annualized Capital Cost ($/Yr)	**$1,500.00**	**$1,500.00**	**$1,500.00**	**$3,940.00**
Thermal Energy Requirement (MJ/Yr)	556,016.6	556,016.6	556,016.6	556,016.6
Calorific Value of Fuel (MJ/Kg or kwh)	41.5	3.6	45.00	-
Volume of Fuel Required (Kg or kwh/Yr)	13,398.0	154,449.1	12,355.9	-
Fuel Costs ($/Kg)	$0.54	$0.14	$1.43	$0.00
Annual Op Costs - Fuel ($/Yr)	**$7,234.92**	**$22,226.39**	**$17,607.19**	**$0.00**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$3,000.00**	**$3,000.00**	**$3,000.00**	**$9,850.00**
Total Annualized Costs ($/Yr)	**$11,734.92**	**$26,726.39**	**$22,107.19**	**$13,790.00**
Total Annual Costs Savings ($/Yr)	**-$2,055.08**	**$12,936.39**	**$8,317.19**	
Total Annual Costs Savings (%)	**-18%**	**48%**	**38%**	

The analysis found that fuel oil-fired dryers have the least total annualized costs due to the assumed low cost at $0.54 per kg. However, switching to geothermal energy will result in costs savings of 38% and 48% compared to gas-fired and electric steam incubators, respectively. Yet, the sensitivity analysis presented below shows that with a slight increase in the CAPEX to $197k, the geothermal option becomes costlier than electric steam by 3%.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the chicken hatchery retrofit project to replace electric steam with geothermal heat, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is moderate with an after-tax equity IRR of 10.36%, payback period of 13 years and an after-tax project IRR of 11.03%. As shown in **Table 73**, the annual cost savings realized by the plant is USD 12,936. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 158,550 while net cashflows to be distributed is USD 129,000 million.

Table 73: Geothermal Chicken Hatchery Retrofit Analysis Results

CHICKEN HATCHERY RESULTS SUMMARY	
Annual Cost Savings	$12,936.39
Total CF to Equity	$158,550
Net CF to Equity	$129,000
Cash on Cash Return	4.37x
After Tax Equity IRR	10.36%
After Tax Project IRR	11.03%
Payback Year	13

- ***Sensitivity Analysis***

Table 74 shows the impact of increases in CAPEX at 20% intervals on the equity IRR, payback period, and cost savings. The results reveal that the chicken hatchery retrofit project will not be viable if CAPEX decreases slightly at the production levels analyzed.

Table 74: Geothermal Chicken Hatchery Retrofit Sensitivity Analysis

		Equity IRR	Payback (Yrs)	Cost Savings ($/Yr)	Cost Savings (%)
CAPEX		10.36%	13	$12,936.39	48%
59,100	-40%	46.94%	3	$18,452.39	69%
78,800	-20%	21.89%	6	$15,694.39	59%
98,500	0%	10.36%	13	$12,936.39	48%
118,200	20%	3.32%	20	$10,178.39	38%
137,900	40%	-1.95%	NONE	$7,420.39	28%
157,600	60%	-7.05%	NONE	$4,662.39	17%
177,300	80%	-14.30%	NONE	$1,904.39	7%
197,000	100%	NEG IRR	NONE	-$853.61	-3%
216,700	120%	NEG IRR	NONE	-$3,611.61	-14%
236,400	140%	NEG IRR	NONE	-$6,369.61	-24%
256,100	160%	NEG IRR	NONE	-$9,127.61	-34%

In conclusion, the chicken hatchery plant retrofit project is estimated to be fairly viable based on the current assumptions. This is mainly because the hatchery process has a relatively low thermal energy requirement/fuel consumption compared to other applications, hence, switching to geothermal energy will only be very viable for large operations with high fuel requirements.

2.3.3 ***Direct Use Geothermal Project:*** *PYRETHRUM DRYING (Greenfield)* ***Applicable Sites:*** *Eburru*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal pyrethrum drying plant with a 1-ton/batch capacity is estimated at USD 294,309 (**Table 75**).

Table 75: Geothermal Pyrethrum Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Construction	60,000
Batch Dryer	65,000
Land Acquisition Cost	6,838.52
Grinding machine	20,000
Pre-cooling machine	30,000
Packaging equipment	10,970
Total CAPEX ($ USD)	**294,309**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 122,652 (**Table 76**).

Table 76: Geothermal Pyrethrum Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	*Units*	Cost/Unit	1st Year (USD)
Cost of Fresh Pyrethrum (incl. Transport)	US$/Kg	0.16	16,466
Electricity Costs	US$/kwh	0.14	2,936
Equipment O&M	% of CAPEX	10.0%	29,431
Labor (Non-payroll)	US$/hr	0.77	44,316
Payroll	US$/Yr	N/A	17,745
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	349
Distribution/Marketing Expenses	% of Rev	0.5%	349
Utilities, Property Tax	US$/sqft	2.0	10,764
Packaging	US$/Kg	0.01	204
Opex Annual Inflator (%)		1%	
TOTAL OPEX			122,652

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal pyrethrum drying to the cost of identified conventional pyrethrum drying systems including open-air sun drying, solar drying, and wood-fired systems. **Table 77** presents the results of the analysis showing the total annualized cost of each system.

Table 77: Pyrethrum Drying Energy Systems Cost Comparison

	PYRETHRUM DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	5.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	65	130	260	260
Max Annual Capacity per Dryer (Kg)	325.0	130,000.0	260,000.0	260,000.0
Volume of Pyrethrum Processed per Year (Kg)	102,000	102,000	102,000	102,000
No. of Dryers Required	314.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$158,000.00	$226,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$18,840.00**	**$4,414.40**	**$7,900.00**	**$9,060.00**
Fuel Requirement (kg/Yr)	-	-	13,712.87	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.07	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$891.34**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.14	0.14
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$2,935.71**	**$2,935.71**
Annual Op Costs - Labour ($/Yr)	**$55,394.53**	**$44,315.62**	**$55,394.53**	**$44,315.62**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$9,420.00**	**$8,828.80**	**$15,800.00**	**$22,650.00**
Cost of Lost Revenue ($/Yr)	$34,939.08	-	-	-
Total Annualized Costs ($/Yr)	**$118,593.61**	**$57,558.82**	**$82,921.58**	**$78,961.34**
Total Annual Costs Savings ($/Yr)	**$39,632.27**	**-$21,402.51**	**$3,960.24**	
Total Annual Costs Savings (%)	**33%**	**-37%**	**5%**	

The analysis found that solar drying has the least total annualized costs, followed by geothermal direct-use, wood-fired dryers and open-air sun drying. Switching to geothermal energy will result in costs savings of 5% and 33% compared to wood-fired dryers and open-air sun drying, respectively.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the pyrethrum drying application, based on the assumptions detailed in **Annex 1**, found that the project is unviable with a negative IRR as the cashflows projected to be generated over the life of the plant at the assumed level of production will be insufficient to pay back the initial investment. As shown in **Table 78**, the average annual revenue generated by the plant of USD 78,434, is much less than the projected average annual expenses of USD 138,564. The total loss to be incurred by investors over the life of the plant is estimated at USD 1.96 million.

Table 78: Geothermal Pyrethrum Drying Analysis Results

PYRETHRUM DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	20,075
Avg Annual Revenue	$78,433.77
Avg Annual Expenses	$138,563.67
Avg EBITDA	#DIV/0!
Total CF to Equity	-$1,867,353
Net CF to Equity	-$1,955,645
Cash on Cash Return	-22.15x
After Tax Equity IRR	NEG IRR
After Tax Project IRR	#NUM!
Payback Year	#N/A

- ***Sensitivity Analysis***

✓ ***CAPEX Scenarios***

Table 79 shows the impact of increases in CAPEX and the quantity of fresh pyrethrum processed at 20% and 25,000kg intervals, respectively, on the equity IRR. The results show that the geothermal pyrethrum drying plant will only be viable if CAPEX decreases by 40% and the quantity of pyrethrum processed annually is increased to 250,000kg.

Table 79: Geothermal Pyrethrum Drying CAPEX Scenarios

		CAPEX						
		$176,585	$235,447	$294,309	$353,170	$412,032	$470,894	$529,755
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	125,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	150,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	-5.25%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	225,000	7.27%	-1.40%	-9.11%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	18.61%	7.38%	0.56%	-4.62%	-11.29%	NEG IRR	NEG IRR

✓ ***OPEX Scenarios***

Table 80 shows the impact of increases in OPEX and the quantity of fresh pyrethrum processed at 20% and 25,000kg intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal pyrethrum drying plant will be viable if OPEX decreases by 20% and the quantity of pyrethrum processed annually is increased to 225,000kg.

Table 80: Geothermal Pyrethrum Drying OPEX Scenarios

		OPEX						
		$73,591	$98,122	$122,652	$147,183	$171,713	$196,244	$220,774
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	125,000	-5.86%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	150,000	3.27%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	11.01%	-5.31%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	18.97%	3.08%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	225,000	28.25%	10.33%	-9.11%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	38.82%	17.62%	0.56%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 81 shows the impact of increases in the price of dried pyrethrum and the quantity of fresh pyrethrum processed at 20% and 25,000kg intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results also reveal that the geothermal pyrethrum drying plant will be viable if prices increase by 20% and the quantity of pyrethrum processed annually is increased to 225,000kg. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable at the production levels analyzed.

Table 81: Geothermal Pyrethrum Drying Price Scenarios

		Price						
		$2.08	$2.77	$3.46	$4.15	$4.84	$5.53	$6.23
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	125,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	-6.30%	4.69%
	150,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	-4.48%	7.66%	19.02%
	175,000	NEG IRR	NEG IRR	NEG IRR	-9.77%	6.87%	20.23%	36.94%
	200,000	NEG IRR	NEG IRR	NEG IRR	2.25%	17.31%	35.84%	57.79%
	225,000	NEG IRR	NEG IRR	-9.11%	10.85%	29.73%	53.78%	79.46%
	250,000	NEG IRR	NEG IRR	0.56%	19.68%	44.29%	72.52%	101.29%

In summary, the geothermal pyrethrum drying plant is estimated to be unviable based on the current assumptions especially given that only 8-9 tons of fresh pyrethrum is currently being produced per month with a potential of increasing to 15 tons/month (180 tons/year). However, it is clear from the sensitivity analysis that the project can be made viable by maximizing the capacity of the plant thereby realizing economies of scale and by exploring opportunities to decrease OPEX and/or increase prices.

2.3.4 ***Direct Use Geothermal Project:*** *FRUIT DRYING (Greenfield)*
Applicable Sites: *Eburru*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal fruit drying plant with a 1-ton/batch capacity is estimated at USD 280,029 (**Table 82**).

Table 82: Geothermal Fruit Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Construction	60,000
Batch Dryer	65,000
Land Acquisition Cost	4,559.01
Fruit peeling machine	3,500
Fruit Slicing Machine	1,500
Blanching machine	3,000
Pre-cooling machine	30,000
Packaging equipment	10,970
Total CAPEX ($ USD)	**280,029**

- ***Operating Costs***

The operating costs for the first year of the fruit drying plant operation are estimated at USD 250,987 (**Table 83**).

Table 83: Geothermal Fruit Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Cost of Fresh Fruit (incl. Transport)	US$/Kg	0.68	169,418
Electricity Costs	US$/kwh	0.14	7,195
Equipment O&M	% of CAPEX	10.0%	28,003
Labor (Non-payroll)	US$/hr	0.77	19,942
Payroll	US$/Yr	N/A	17,745
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	1,591
Distribution/Marketing Expenses	% of Rev	0.5%	1,591
Utilities, Property Tax	US$/sqft	2.0	3,582
Packaging	US$/Kg	0.05	1,827
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**250,987**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal fruit drying to the cost of identified conventional fruit drying systems including open air sun drying, solar drying, and wood-fired systems. **Table 84** presents the results of the analysis showing the total annualized cost of each system.

Table 84: Fruit Drying Energy Systems Cost Comparison

	FRUIT DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	10.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	117	234	468	468
Max Annual Capacity per Dryer (Kg)	1,170.0	234,000.0	468,000.0	468,000.0
Volume of Fruit Processed per Year (Kg)	250,000	250,000	250,000	250,000
No. of Dryers Required	214.0	2.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$158,000.00	$226,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$12,840.00**	**$8,828.80**	**$7,900.00**	**$9,060.00**
Fuel Requirement (kg/Yr)	-	-	35,063.25	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.07	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$2,279.11**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.14	0.14
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$7,195.38**	**$7,195.38**
Annual Op Costs - Labour ($/Yr)	**$24,927.54**	**$19,942.03**	**$24,927.54**	**$19,942.03**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$6,420.00**	**$17,657.60**	**$15,800.00**	**$22,650.00**
Cost of Lost Revenue ($/Yr)	$159,167.94	-	-	-
Total Annualized Costs ($/Yr)	**$203,355.48**	**$46,428.43**	**$58,102.03**	**$58,847.41**
Total Annual Costs Savings ($/Yr)	**$144,508.07**	**-$12,418.98**	**-$745.38**	
Total Annual Costs Savings (%)	**71%**	**-27%**	**-1%**	

The analysis found that solar drying has the least total annualized costs, followed by wood-fired dryers, geothermal direct-use and open-air sun drying. Wood-fired dryers have a lower annualized cost compared to geothermal heating due to the assumed low cost at $0.07 per kg. However, geothermal energy will be cheaper with any slight increase in the cost of firewood from the base value assumed. Switching to geothermal energy will also result in costs savings of 71% compared to open-air sun drying.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the fruit drying application, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is attractive with an after-tax equity IRR of 31.5%, payback period of 4 years and an after-tax project IRR of 20.85%. As shown in **Table 85**, the average annual revenue generated by the plant is USD 357,214, while the average total annual expenses are USD 283,547. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 1.14 million, while net cashflows to be distributed is USD 1.06 million. It is worth noting that the returns for this application are higher compared to the fish drying application mainly due to the lower cost of fresh fruits needed as input for the plant.

Table 85: Geothermal Fruit Drying Analysis Results

FRUIT DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	39,089
Avg Annual Revenue	$357,214.26
Avg Annual Expenses	$283,547.33
Avg EBITDA	$73,666.93
Total CF to Equity	$1,142,428
Net CF to Equity	$1,058,419
Cash on Cash Return	12.60x
After Tax Equity IRR	31.50%
After Tax Project IRR	20.85%
Payback Year	4

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 86 shows the impact of increases in CAPEX and the quantity of fresh fruits processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the geothermal fruit drying plant will not be viable at the base production level of 250,000kg if CAPEX increases by 60% and above.

Table 86: Geothermal Fruit Drying CAPEX Scenarios

		CAPEX						
		$168,017	$224,023	$280,029	$336,035	$392,041	$448,046	$504,052
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	150,000	12.81%	3.10%	-3.33%	-10.54%	NEG IRR	NEG IRR	NEG IRR
	200,000	46.17%	23.82%	13.09%	6.67%	1.92%	-1.88%	-5.43%
	250,000	86.36%	51.26%	31.50%	20.14%	13.21%	8.41%	4.59%
	300,000	127.05%	81.45%	54.34%	37.01%	25.78%	18.40%	13.27%
	350,000	167.74%	111.95%	78.51%	56.40%	41.08%	30.35%	22.80%
	400,000	208.41%	142.47%	102.90%	76.55%	57.88%	44.20%	34.07%

  ✓ ***OPEX Scenarios***

Table 87 shows the impact of increases in OPEX and the quantity of fresh fruit processed at 20% and 50,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal fruit drying plant will not be viable at the base production level of 250,000kg if OPEX increases by 20% and above.

Table 87: Geothermal Fruit Drying OPEX Scenarios

		OPEX						
		$150,592	$200,790	$250,987	$301,185	$351,382	$401,580	$451,777
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	14.61%	-2.26%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	150,000	45.34%	18.27%	-3.33%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	82.12%	44.35%	13.09%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	119.48%	74.64%	31.50%	-0.81%	NEG IRR	NEG IRR	NEG IRR
	300,000	156.87%	105.49%	54.34%	11.19%	NEG IRR	NEG IRR	NEG IRR
	350,000	194.25%	136.39%	78.51%	23.80%	NEG IRR	NEG IRR	NEG IRR
	400,000	231.62%	167.29%	102.90%	39.31%	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 88 shows the impact of increases in the price of dried fruits and the quantity of fresh fruits processed at 20% and 50,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results also reveal that the geothermal fruit drying plant will not be viable if prices decrease by 20% and above at the production levels analyzed except for the 20% price decrease at 400,000kg scenario. In addition, all the tables show that under the current base assumptions for CAPEX, OPEX and pricing, the plant will not be viable if the quantity of fresh fruit processed falls below 200,000kg.

Table 88: Geothermal Fruit Drying Price Scenarios

		Price						
		$4.85	$6.47	$8.09	$9.71	$11.33	$12.95	$14.56
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	NEG IRR	NEG IRR	NEG IRR	-4.78%	10.84%	26.87%	47.15%
	150,000	NEG IRR	NEG IRR	-3.33%	19.57%	48.93%	82.29%	116.06%
	200,000	NEG IRR	NEG IRR	13.09%	50.72%	95.41%	140.46%	185.50%
	250,000	NEG IRR	NEG IRR	31.50%	86.02%	142.34%	198.63%	254.90%
	300,000	NEG IRR	0.50%	54.34%	121.68%	189.25%	256.78%	324.30%
	350,000	NEG IRR	9.29%	78.51%	157.35%	236.16%	314.93%	393.69%
	400,000	NEG IRR	17.96%	102.90%	193.01%	283.05%	373.07%	463.08%

In conclusion, the geothermal fruit drying plant is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that a slight increase in OPEX or decrease in prices will make the plant unviable.

2.3.5 ***Direct Use Geothermal Project:*** *VEGETABLE DRYING (Greenfield)*
Applicable Sites: *Menengai*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal vegetable drying plant with a 1-ton/batch capacity is estimated at USD 277,309 (**Table 89**).

Table 89: Geothermal Vegetable Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Construction	60,000
Batch Dryer	65,000
Land Acquisition Cost	6,838.52
Blanching machine	3,000
Pre-cooling machine	30,000
Packaging equipment	10,970
Total CAPEX ($ USD)	**277,309**

- ***Operating Costs***

The operating costs for the first year of plant operation is estimated at USD 285,003 (**Table 90**).

Table 90: Geothermal Vegetable Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	*Units*	Cost/Unit	1st Year (USD)
Cost of Fresh Veg (incl. Transport)	US$/Kg	0.34	186,360
Electricity Costs	US$/kwh	0.14	15,830
Equipment O&M	% of CAPEX	10.0%	27,731
Labor (Non-payroll)	US$/hr	0.77	16,270
Payroll	US$/Yr	N/A	17,745
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	1,451
Distribution/Marketing Expenses	% of Rev	0.5%	1,451
Utilities, Property Tax	US$/sqft	2.0	10,764
Packaging	US$/Kg	0.09	7,309
Other 1	US$/Yr	-	-
Other 2	US$/Yr	-	-
Other 3	US$/Yr	-	-
Other 4	US$/Yr	-	-
Other 5	US$/Yr	-	-
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**285,003**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of a geothermal vegetable drying plant to the cost of identified conventional vegetable drying systems including open-air sun drying, solar drying and wood-fired drying systems. **Table 91** presents the results of the analysis showing the total annualized cost of each system.

Table 91: Vegetable Drying Energy Systems Cost Comparison

	VEGETABLE DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	5.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	300	600	600	600
Max Annual Capacity per Dryer (Kg)	1,500.0	600,000.0	600,000.0	600,000.0
Volume of Veg Processed per Year (Kg)	550,000	550,000	550,000	550,000
No. of Dryers Required	367.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$158,000.00	$226,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$22,020.00**	**$4,414.40**	**$7,900.00**	**$9,060.00**
Fuel Requirement (kg/Yr)	-	-	79,019.35	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.07	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$5,136.26**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.14	0.14
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$15,829.83**	**$15,829.83**
Annual Op Costs - Labour ($/Yr)	**$20,337.15**	**$16,269.72**	**$20,337.15**	**$16,269.72**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$11,010.00**	**$8,828.80**	**$15,800.00**	**$22,650.00**
Cost of Lost Revenue ($/Yr)	$145,109.25	-	-	-
Total Annualized Costs ($/Yr)	**$198,476.40**	**$29,512.92**	**$65,003.24**	**$63,809.56**
Total Annual Costs Savings ($/Yr)	**$134,666.85**	**-$34,296.63**	**$1,193.69**	
Total Annual Costs Savings (%)	**68%**	**-116%**	**2%**	

The analysis found that solar drying has the least total annualized costs, followed by geothermal direct-use, wood-fired dryers and open-air sun drying. Switching to geothermal energy will result in costs savings of 2% and 68% compared to wood-fired dryers and open-air sun drying, respectively.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the vegetable drying application, based on the assumptions detailed in **Annex 1**, found that the project is unviable with a negative IRR as the cashflows projected to be generated over the life of the plant at the assumed production level will be insufficient to pay back the initial investment. As shown in **Table 92**, the average annual revenue generated by the plant of USD 325,811 is only slightly higher than the projected average annual expenses projected of USD 321,976. The total loss to be incurred by investors over the life of the plant is estimated at USD 330,394.

Table 92: Geothermal Vegetable Drying Analysis Results

VEGETABLE DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	78,178
Avg Annual Revenue	$325,810.56
Avg Annual Expenses	$321,975.66
Avg EBITDA	$3,834.90
Total CF to Equity	-$247,201
Net CF to Equity	-$330,394
Cash on Cash Return	-3.97x
After Tax Equity IRR	-14.28%
After Tax Project IRR	-7.69%
Payback Year	#N/A

- ***Sensitivity Analysis***

✓ ***CAPEX Scenarios***

Table 93 shows the impact of increases in CAPEX and the quantity of fresh vegetables processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the geothermal vegetable drying plant will only be viable if CAPEX decreases by 40% and processing volume increases to 600,000kg.

Table 93: Geothermal Vegetable Drying CAPEX Scenarios

		CAPEX						
		$166,385	$221,847	$277,309	$332,770	$388,232	$443,694	$499,155
	-14.28%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	350,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	400,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	450,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	500,000	-2.39%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	550,000	5.25%	-3.47%	-14.28%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	600,000	12.21%	2.46%	-4.13%	-12.64%	NEG IRR	NEG IRR	NEG IRR

✓ ***OPEX Scenarios***

Table 94 shows the impact of increases in OPEX and the quantity of fresh vegetable processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal vegetable drying plant will be attractive at the current production level if OPEX decreases by 20%.

Table 94: Geothermal Vegetable Drying OPEX Scenarios

		OPEX						
		$171,002	$228,002	$285,003	$342,003	$399,004	$456,005	$513,005
	-14.28%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	16.72%	-7.96%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	350,000	26.71%	0.76%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	400,000	38.32%	7.33%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	450,000	50.96%	13.61%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	500,000	64.05%	20.44%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	550,000	77.31%	28.19%	-14.28%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	600,000	90.63%	36.82%	-4.13%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 95 shows the impact of increases in the price of dried vegetables and the quantity of fresh vegetables processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX. The results also reveal that the geothermal vegetable drying plant will be very viable at the current production level if prices increase by 20%. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable at the production levels analyzed.

Table 95: Geothermal Vegetable Drying Pricing Scenarios

		Price						
		$2.21	$2.95	$3.69	$4.43	$5.17	$5.90	$6.64
	-14.28%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	9.14%	29.51%	55.85%
	350,000	NEG IRR	NEG IRR	NEG IRR	-2.74%	19.63%	48.29%	80.86%
	400,000	NEG IRR	NEG IRR	NEG IRR	5.05%	32.34%	68.43%	106.08%
	450,000	NEG IRR	NEG IRR	NEG IRR	12.19%	46.93%	88.88%	131.32%
	500,000	NEG IRR	NEG IRR	NEG IRR	19.75%	62.36%	109.40%	156.56%
	550,000	NEG IRR	NEG IRR	-14.28%	28.46%	78.07%	129.93%	181.79%
	600,000	NEG IRR	NEG IRR	-4.13%	38.26%	93.86%	150.46%	207.02%

In summary, the geothermal vegetable drying plant is estimated to be unviable based on the current set of assumptions mainly due to the high OPEX values. However, it is clear from the sensitivity analysis that the plant can be made viable by adopting cost cutting measures to minimize OPEX and/or sell the dried produce at higher prices.

Figure 1: Geothermal Grain Dryer at Menengai, Kenya

One direct use application that has proven successful in Kenya is a grain dryer at the Menengai geothermal field (**Figure 1**). The dryer was installed by Kenya's Geothermal Development Company with funding from Iceland. The dryer operates using geothermal heat instead of heavy oil, which is normally used to fire industrial boilers. This leads to a significant reduction in the cost of drying. It also helps reduce post-harvest losses associated with poor drying

2.3.6 ***Direct Use Geothermal Project:*** *GREENHOUSE HEATING (Retrofit)* ***Applicable Sites:*** *Menengai*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of retrofitting a 5,000 sqm greenhouse to operate on geothermal heat is estimated at USD 458,500 (**Table 96**).

Table 96: Geothermal Greenhouse Retrofit Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	200,000
Pumps	3,500
Well Drilling	30,000
Pipes	225,000
Total CAPEX ($ USD)	**458,500**

- ***Operating Costs***

It is assumed that all the regular operating costs of the existing facility (except fuel costs which will be eliminated by the retrofit) will remain the same, while the annual O&M cost of the geothermal direct use system and retrofits is estimated at 10% of project CAPEX - $45,850.

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal greenhouse heating to the cost of identified conventional greenhouse heating systems including fuel oil and LPG-fueled systems. **Table 97** presents the results of the analysis showing the total annualized cost of each system.

Table 97: Greenhouse Heating Systems Cost Comparison

	GREENHOUSE HEATING SYSTEMS COST COMPARISON		
	Fuel Oil	LPG	Geothermal
Total Heating Equipment Costs ($)	$40,000.00	$40,000.00	$458,500.00
Design Life - Heating Equipment (Yrs)	20	20	25
Annualized Capital Cost ($/Yr)	**$2,000.00**	**$2,000.00**	**$18,340.00**
Thermal Energy Requirement (MJ/Yr)	23,938,972.8	23,938,972.8	23,938,972.8
Calorific Value of Fuel (MJ/Kg)	41.5	46.3	-
Volume of Fuel Required (Kg/Yr)	576,842.7	517,040.4	-
Fuel Costs ($/Kg)	$0.54	$1.43	$0.00
Annual Op Costs - Fuel ($/Yr)	**$311,495.07**	**$739,367.84**	**$0.00**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$4,000.00**	**$4,000.00**	**$45,850.00**
Total Annualized Costs ($/Yr)	**$317,495.07**	**$745,367.84**	**$64,190.00**
Total Annual Costs Savings ($/Yr)	**$253,305.07**	**$681,177.84**	
Total Annual Costs Savings (%)	**80%**	**91%**	

The analysis found that geothermal direct-use has the least total annualized costs, followed by fuel oil and lastly LPG. Switching to geothermal energy will result in costs savings of 80% and 91% compared to fuel oil and LPG, respectively, mainly due to the avoided fuel expenditure. However, the sensitivity analysis presented below shows that with a major increase in the CAPEX to USD 2.3 million, the geothermal option becomes costlier than fuel oil by 1%.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the greenhouse retrofit project, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is very attractive with an after-tax equity IRR of 106.8%, payback period of 1 year and an after-tax project IRR of 44.2%. As shown in **Table 98**, the annual cost savings (compared to fuel oil) realized by the plant is USD 253,305. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 4.36 million while net cashflows to be distributed is USD 4.2 million.

Table 98: Geothermal Greenhouse Retrofit Analysis Results

GREENHOUSE HEATING RESULTS SUMMARY	
Annual Cost Savings	$253,305.07
Total CF to Equity	$4,358,431
Net CF to Equity	$4,220,881
Cash on Cash Return	30.69x
After Tax Equity IRR	106.80%
After Tax Project IRR	44.18%
Payback Year	1

- ***Sensitivity Analysis***

Table 99 shows the impact of increases in CAPEX at 50% intervals on the equity IRR, payback period, and cost savings. The results reveal that the greenhouse retrofit will not be viable if CAPEX increases significantly to $1.4 million at the greenhouse size analyzed.

Table 99: Geothermal Greenhouse Retrofit Sensitivity Analysis

		Equity IRR	Payback (Yrs)	Cost Savings ($/Yr)	Cost Savings (%)
CAPEX		106.80%	1	$253,305.07	80%
458,500	0%	106.80%	1	$253,305.07	80%
687,750	50%	49.23%	3	$221,210.07	70%
917,000	100%	23.26%	6	$189,115.07	60%
1,146,250	150%	11.23%	13	$157,020.07	49%
1,375,500	200%	4.06%	19	$124,925.07	39%
1,604,750	250%	-1.26%	NONE	$92,830.07	29%
1,834,000	300%	-6.11%	NONE	$60,735.07	19%
2,063,250	350%	-12.62%	NONE	$28,640.07	9%
2,292,500	400%	NEG IRR	NONE	-$3,454.93	-1%
2,521,750	450%	NEG IRR	NONE	-$35,549.93	-11%
2,751,000	500%	NEG IRR	NONE	-$67,644.93	-21%

In conclusion, the greenhouse retrofit project is estimated to be very viable based on the current assumptions. However, it is clear from the sensitivity analysis that a major increase in CAPEX will make the project unviable, although it is also worth noting that the cost savings to be realized could be much higher than the values depicted herein depending on the fuel type.

Figure 2: Oserian Flower Farms at Olkaria, Kenya

Another successful direct use application in Kenya is growing roses in geothermally heated greenhouses. In Naivasha, Kenya, a 50-hecatre flower farm called Oserian (**Figure 2**) utilizes geothermal heat from the Olkaria geothermal field. The privately-owned Oserian Development Company has been cultivating flowers sustainably and using geothermal heat in greenhouses since 2003. The use of geothermal heat in the greenhouses keeps humidity low, preventing fungal infections in flowers, resulting in a lower cost of production. Greenhouse geothermal heating improves flower quality and helps increase production. The Oserian Farm annually exports 400 million stems of roses to European countries and the United States.[8]

[8] Van Nguyen, M., et al., 2015, "Uses of geothermal energy in food and agriculture: Opportunities for developing countries," Food and Agriculture Organization of the United Nations (FAO, 2015): http://www.eu-fire.hu/documents/fao.pdf

2.4 RWANDA

Geothermal Site	Categorized Direct Use Applications
Bugarama	1. Fish drying 2. Tea processing
Gisenyi	1. Vegetable/grain drying 2. Fish drying
Karago	1. Vegetable/grain drying 2. Milk pasteurization

2.4.1 ***Direct Use Geothermal Project:*** *FISH DRYING (Greenfield)* ***Applicable Sites:*** *Bugarama, Gisenyi*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal fish drying plant with a 1-ton/batch capacity is estimated at USD 268,636 (**Table 100**). This estimated cost assumes that an adequate geothermal hot fluid temperature can be accessed at 30m depth, which results in minimal drilling costs.[9]

Table 100: Geothermal Fish Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Constr. Of Drying Station	150,000
Drying Cabinet	2,000
Packaging equipment	10,970
Land Acquisition Cost	4,165.97
Total CAPEX ($ USD)	**268,636**

- ***Operating Costs***

The operating costs for the first year of plant operation is estimated at USD 528,586 (**Table 101**).

[9] Nshimyumuremyi, E., "Preliminary Feasibility Analysis on the Direct Use of Geothermal Energy in Rwanda: Case Study Gisenyi Hot Spring," KTH Industrial Engineering and Management, (2014): https://www.diva-portal.org/smash/get/diva2:742038/FULLTEXT01.pdf

Table 101: Geothermal Fish Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Cost of Fresh Fish (incl. Transport)	US$/Kg	1.50	450,000
Electricity Costs	US$/kwh	0.13	7,686
Equipment O&M	% of CAPEX	10.0%	26,864
Labor (Non-payroll)	US$/hr	0.78	13,982
Payroll	US$/Yr	N/A	17,605
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	2,854
Distribution/Marketing Expenses	% of Rev	0.5%	2,854
Utilities, Property Tax	US$/sqft	2.0	3,582
Packaging	US$/Kg	0.05	3,067
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**528,586**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal fish drying to the cost of identified conventional fish drying systems including open air sun drying, solar drying, and wood-fired systems. **Table 102** presents the results of the analysis showing the total annualized cost of each system.

Table 102: Fish Drying Energy Systems Cost Comparison

	FISH DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	10.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	150	300	300	300
Max Annual Capacity per Dryer (Kg)	1,500.0	300,000.0	300,000.0	300,000.0
Volume of Fish Processed per Year (Kg)	300,000	300,000	300,000	300,000
No. of Dryers Required	200.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$185,000.00	$253,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$12,000.00**	**$4,414.40**	**$9,250.00**	**$10,140.00**
Fuel Requirement (kg/Yr)	-	-	39,135.66	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.03	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$1,174.07**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.13	0.13
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$7,686.21**	**$7,686.21**
Annual Op Costs - Labour ($/Yr)	**$17,477.54**	**$13,982.03**	**$17,477.54**	**$13,982.03**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$6,000.00**	**$8,828.80**	**$18,500.00**	**$25,350.00**
Cost of Lost Revenue ($/Yr)	$285,450.00	-	-	-
Total Annualized Costs ($/Yr)	**$320,927.54**	**$27,225.23**	**$54,087.82**	**$57,158.24**
Total Annual Costs Savings ($/Yr)	**$263,769.30**	**-$29,933.01**	**-$3,070.42**	
Total Annual Costs Savings (%)	**82%**	**-110%**	**-6%**	

The analysis found that solar drying has the least total annualized costs, followed by wood-fired dryers, geothermal direct-use and open-air sun drying. Wood-fired dryers have a lower annualized cost compared to geothermal heating due to the assumed low cost at $0.03 per kg. However, geothermal energy will be cheaper with any slight increase in the cost of firewood from the base value assumed. Switching to geothermal energy will also result in costs savings of 82% compared to open-air sun drying.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the fish drying application, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is moderate with an after-tax equity IRR of 11.55%, payback period of 13 years and an after-tax project IRR of 13.84%. As shown in **Table 103**, the average annual revenue generated by the plant is USD 640,738, while the average total annual expenses are USD 597,158. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 507,351, while net cashflows to be distributed is USD 426,760.

Table 103: Geothermal Fish Drying Analysis Results

FISH DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	65,604
Avg Annual Revenue	$640,738
Avg Annual Expenses	$597,158
Avg EBITDA	$43,580
Total CF to Equity	$507,351
Net CF to Equity	$426,760
Cash on Cash Return	5.30x
After Tax Equity IRR	11.55%
After Tax Project IRR	13.84%
Payback Year	13

- ***Sensitivity Analysis***

  - ✓ ***CAPEX Scenarios***

Table 104 shows the impact of increases in CAPEX and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the geothermal fish drying plant will not be viable if CAPEX increases by 20% and above at the production levels analyzed.

Table 104: Geothermal Fish Drying CAPEX Scenarios

		CAPEX						
		$161,182	$214,909	$268,636	$322,363	$376,090	$429,818	$483,545
	11.55%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	-3.61%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	3.44%	-4.48%	-14.18%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	10.19%	0.97%	-5.01%	-12.66%	NEG IRR	NEG IRR	NEG IRR
	225,000	16.92%	6.00%	-0.52%	-5.37%	-11.74%	NEG IRR	NEG IRR
	250,000	24.62%	11.04%	3.53%	-1.54%	-5.65%	-11.11%	NEG IRR
	275,000	33.45%	16.03%	7.53%	1.88%	-2.28%	-5.87%	-10.66%
	300,000	43.14%	21.57%	11.55%	5.20%	0.70%	-2.85%	-6.06%

  - ✓ ***OPEX Scenarios***

Table 105 shows the impact of increases in OPEX and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal fish drying plant will not be viable if OPEX increases by 20% and above at the production levels analyzed.

Table 105: Geothermal Fish Drying OPEX Scenarios

		OPEX						
		$317,151	$422,869	$528,586	$634,303	$740,020	$845,737	$951,454
	11.55%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	65.27%	20.12%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	85.53%	30.52%	-14.18%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	105.86%	42.50%	-5.01%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	225,000	126.19%	55.32%	-0.52%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	146.51%	68.48%	3.53%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	275,000	166.83%	81.76%	7.53%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	300,000	187.15%	95.07%	11.55%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 106 shows the impact of increases in the price of dry fish and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results also reveal that the geothermal fish drying plant will not be viable if prices decrease by 20% and above at the production levels analyzed. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable if the quantity of fresh fish processed falls below 300,000kg.

Table 106: Geothermal Fish Drying Price Scenarios

		Price						
		$5.19	$6.92	$8.65	$10.38	$12.11	$13.84	$15.57
	11.55%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	NEG IRR	NEG IRR	NEG IRR	19.52%	63.79%	112.93%	162.12%
	175,000	NEG IRR	NEG IRR	-14.18%	30.84%	86.40%	143.81%	201.16%
	200,000	NEG IRR	NEG IRR	-5.01%	43.98%	109.08%	174.67%	240.18%
	225,000	NEG IRR	NEG IRR	-0.52%	58.03%	131.77%	205.52%	279.19%
	250,000	NEG IRR	NEG IRR	3.53%	72.41%	154.45%	236.35%	318.20%
	275,000	NEG IRR	NEG IRR	7.53%	86.88%	177.11%	267.19%	357.21%
	300,000	NEG IRR	NEG IRR	11.55%	101.37%	199.77%	298.01%	396.21%

In summary, the geothermal fish drying plant is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that a slight increase in CAPEX/OPEX or decrease in prices will make the plant unviable. In addition, the projected investor returns are moderate and could become more attractive if the project is supported by a grant and/or concessional debt with much lower interest rate than the 16.7% assumed.

2.4.2 ***Direct Use Geothermal Project:*** *TEA PROCESSING (Retrofit)*
Applicable Sites: *Bugarama*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of retrofitting a tea drying plant, producing 2,000 tons of processed tea per year, to operate on geothermal heat is estimated at USD 118,500 (**Table 107**).

Table 107: Geothermal Tea Drying Plant Retrofit Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	40,000
Pumps	3,500
Well Drilling	30,000
Pipes	45,000
Total CAPEX ($ USD)	**118,500**

- ***Operating Costs***

It is assumed that all the regular operating costs of the existing facility (except fuel costs which will be eliminated by the retrofit and reduced labor costs) will remain the same, while the annual O&M cost of the geothermal direct-use system and retrofits is estimated at 10% of project CAPEX - $11,850.

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal tea drying to the cost of identified conventional tea drying systems including diesel-fired and wood-fired dryers. **Table 108** presents the results of the analysis showing the total annualized cost of each system.

Table 108: Tea Drying Energy Systems Cost Comparison

	TEA DRYING ENERGY SYSTEMS COST COMPARISON		
	Diesel	Wood	Geothermal
Output per Batch per Dryer (Kg)	1,722.9	1,722.9	1,722.9
No. of Batches per Year per Dryer	600	600	600
Annual Output per Dryer (Kg)	1,033,738.8	1,033,738.8	1,033,738.8
Volume of Processed Tea per Year (Kg)	2,067,478	2,067,478	2,067,478
No. of Dryers Required	2.0	2.0	2.0
Heating Equipment Costs per Dryer ($)	$20,000.00	$30,000.00	$118,500.00
Design Life - Heating Equipment (Yrs)	20	20	25
Annualized Capital Cost ($/Yr)	**$2,000.00**	**$3,000.00**	**$4,740.00**
Fuel Requirement (kWh/Kg)	5.50	5.50	-
Fuel Costs ($/kWh)	$0.08	$0.02	$0.00
Annual Op Costs - Fuel ($/Yr)	**$909,690.12**	**$204,680.28**	**$0.00**
Electricity Requirement (kWh/Kg)	1.00	1.00	1.00
Electricity Cost ($/kWh)	$0.13	$0.13	$0.13
Annual Op Costs - Electricity ($/Yr)	**$264,851.11**	**$264,851.11**	**$264,851.11**
Plant Labor Required per Dryer	30.00	40.00	30.00
Total Plant Labor Required	60.00	80.00	60.00
Labor Costs ($/hr)	$0.78	$0.78	$0.78
No. of Drying Days per Year	300.00	300.00	300.00
Annual Op Costs - Labour ($/Yr)	**$279,640.57**	**$372,854.09**	**$279,640.57**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$4,000.00**	**$6,000.00**	**$11,850.00**
Cost of Lost Revenue ($/Yr)	-	-	-
Other Costs ($/Yr)	-	-	-
Total Annualized Costs ($/Yr)	**$1,460,181.80**	**$851,385.48**	**$561,081.68**
Total Annual Costs Savings ($/Yr)	**$899,100.12**	**$290,303.80**	
Total Annual Costs Savings (%)	**62%**	**34%**	

The analysis found that geothermal direct use has the least total annualized costs, followed by firewood and diesel. Switching to geothermal energy will result in costs savings of 34% and 62% compared to wood and diesel, respectively, mainly due to the avoided fuel expenditure. However, the sensitivity analysis presented below shows that with a major increase in the CAPEX to $2.3 million, the geothermal option becomes costlier than wood by 1%.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the geothermal tea drying plant retrofit project, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is very attractive with an after-tax equity IRR of 519.88%, payback period of 1 year and an after-tax project IRR of 179.05%. As shown in **Table 109**, the annual cost savings realized by the plant is USD 290,304. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 4.58 million while net cashflows to be distributed is USD 4.55 million.

Table 109: Geothermal Tea Drying Plant Retrofit Analysis Results

TEA PROCESSING RESULTS SUMMARY	
Annual Cost Savings	$290,303.80
Total CF to Equity	$4,583,907
Net CF to Equity	$4,548,357
Cash on Cash Return	127.94x
After Tax Equity IRR	519.88%
After Tax Project IRR	179.05%
Payback Year	1

- ***Sensitivity Analysis***

Table 110 shows the impact of increases in CAPEX at 200% intervals on the equity IRR, payback period, and cost savings. The results reveal that the tea processing plant retrofit will not be viable if CAPEX increases up to USD 1.5 million and above.

Table 110: Geothermal Tea Drying Plant Retrofit Sensitivity Analysis

		Equity IRR	Payback (Yrs)	Cost Savings ($/Yr)	Cost Savings (%)
CAPEX		519.88%	1	$290,303.80	34%
118,500	0%	519.88%	1	$290,303.80	34%
355,500	200%	129.58%	1	$257,123.80	30%
592,500	400%	59.20%	2	$223,943.80	26%
829,500	600%	32.83%	4	$190,763.80	22%
1,066,500	800%	19.89%	6	$157,583.80	19%
1,303,500	1000%	11.81%	11	$124,403.80	15%
1,540,500	1200%	6.04%	15	$91,223.80	11%
1,777,500	1400%	0.36%	25	$58,043.80	7%
2,014,500	1600%	-7.18%	NONE	$24,863.80	3%
2,251,500	1800%	NEG IRR	NONE	-$8,316.20	-1%
2,488,500	2000%	NEG IRR	NONE	-$41,496.20	-5%

In conclusion, the geothermal tea processing plant retrofit project is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that significant increases in CAPEX will result in lower cost savings which would make the retrofit unviable.

2.4.3 ***Direct Use Geothermal Project:*** *VEGETABLE/GRAIN DRYING (Greenfield)* ***Applicable Sites:*** *Gisenyi, Karago*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal vegetable drying plant with a 1-ton/batch capacity is estimated at USD 276,719 (**Table 111**).

Table 111: Geothermal Vegetable Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Construction	60,000
Batch Dryer	65,000
Land Acquisition Cost	6,248.95
Blanching machine	3,000
Pre-cooling machine	30,000
Packaging equipment	10,970
Total CAPEX ($ USD)	**276,719**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 283,109 (**Table 112**).

Table 112: Geothermal Vegetable Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	*Units*	Cost/Unit	1st Year (USD)
Cost of Fresh Veg (incl. Transport)	US$/Kg	0.34	186,360
Electricity Costs	US$/kwh	0.13	14,091
Equipment O&M	% of CAPEX	10.0%	27,672
Labor (Non-payroll)	US$/hr	0.78	16,312
Payroll	US$/Yr	N/A	17,605
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	1,451
Distribution/Marketing Expenses	% of Rev	0.5%	1,451
Utilities, Property Tax	US$/sqft	2.0	10,764
Packaging	US$/Kg	0.09	7,309
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**283,109**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of a geothermal vegetable drying plant to the cost of identified conventional vegetable drying systems including open air sun drying, solar drying and wood-fired drying systems. **Table 113** presents the results of the analysis showing the total annualized cost of each system.

Table 113: Vegetable Drying Energy Systems Cost Comparison

	VEGETABLE DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	5.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	300	600	600	600
Max Annual Capacity per Dryer (Kg)	1,500.0	600,000.0	600,000.0	600,000.0
Volume of Veg Processed per Year (Kg)	550,000	550,000	550,000	550,000
No. of Dryers Required	367.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$158,000.00	$226,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$22,020.00**	**$4,414.40**	**$7,900.00**	**$9,060.00**
Fuel Requirement (kg/Yr)	-	-	79,019.35	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.03	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$2,370.58**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.13	0.13
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$14,091.39**	**$14,091.39**
Annual Op Costs - Labour ($/Yr)	**$20,390.46**	**$16,312.37**	**$20,390.46**	**$16,312.37**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$11,010.00**	**$8,828.80**	**$15,800.00**	**$22,650.00**
Cost of Lost Revenue ($/Yr)	$145,109.25	-	-	-
Total Annualized Costs ($/Yr)	**$198,529.71**	**$29,555.57**	**$60,552.42**	**$62,113.75**
Total Annual Costs Savings ($/Yr)	**$136,415.96**	**-$32,558.19**	**-$1,561.33**	
Total Annual Costs Savings (%)	**69%**	**-110%**	**-3%**	

The analysis found that solar drying has the least total annualized costs, followed by wood-fired dryers (due to the assumed low cost of firewood at $0.03 per kg), geothermal direct use, and open-air sun drying.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the vegetable drying application, based on the assumptions detailed in **Annex 1**, found that the project is unviable with a negative IRR as the cashflows projected to be generated over the life of the plant at the assumed production level will be insufficient to pay back the initial investment. As shown in **Table 114**, the average annual revenue generated by the plant of USD 325,811 is only slightly higher than the projected average annual expenses of USD 319,836. The total loss to be incurred by investors over the life of the plant is estimated at USD 344,911. The main reason for the difference in result compared to Ethiopia and Tanzania is the higher cost of fresh vegetables.

Table 114: Geothermal Vegetable Drying Analysis Results

VEGETABLE DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	78,178
Avg Annual Revenue	$325,810.56
Avg Annual Expenses	$319,835.62
Avg EBITDA	$5,974.94
Total CF to Equity	-$261,895
Net CF to Equity	-$344,911
Cash on Cash Return	-4.15x
After Tax Equity IRR	-11.45%
After Tax Project IRR	-4.54%
Payback Year	#N/A

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 115 shows the impact of increases in CAPEX and the quantity of fresh vegetables processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the geothermal vegetable drying plant will only be viable if CAPEX decreases by 40% and processing volume increases to 600,000kg.

Table 115: Geothermal Vegetable Drying CAPEX Scenarios

		CAPEX						
		$166,031	$221,375	$276,719	$332,063	$387,407	$442,750	$498,094
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	350,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	400,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	450,000	-15.56%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	500,000	-2.22%	-12.71%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	550,000	4.52%	-3.44%	-11.45%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	600,000	11.08%	1.75%	-4.18%	-10.72%	NEG IRR	NEG IRR	NEG IRR

  ✓ ***OPEX Scenarios***

Table 116 shows the impact of increases in OPEX and the quantity of fresh vegetable processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal vegetable drying plant will be attractive at the current production level if OPEX decreases by 20%.

Table 116: Geothermal Vegetable Drying OPEX Scenarios

		OPEX						
		$169,865	$226,487	$283,109	$339,730	$396,352	$452,974	$509,595
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	13.63%	-8.18%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	350,000	22.11%	-0.58%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	400,000	32.22%	5.32%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	450,000	43.65%	11.24%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	500,000	55.79%	17.15%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	550,000	68.22%	23.85%	-11.45%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	600,000	80.76%	31.45%	-4.18%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

  ✓ ***Price Scenarios***

Table 117 shows the impact of increases in the price of dried vegetables and the quantity of fresh vegetables processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX. The results also reveal that the geothermal vegetable drying plant will be very viable at the current production level if prices increase by 20%. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable at the production levels analyzed.

Table 117: Geothermal Vegetable Drying Price Scenarios

		Price						
		$2.21	$2.95	$3.69	$4.43	$5.17	$5.90	$6.64
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	6.95%	24.71%	48.26%
	350,000	NEG IRR	NEG IRR	NEG IRR	-3.51%	16.40%	41.46%	71.64%
	400,000	NEG IRR	NEG IRR	NEG IRR	3.43%	27.37%	60.17%	95.38%
	450,000	NEG IRR	NEG IRR	NEG IRR	10.09%	40.47%	79.41%	119.15%
	500,000	NEG IRR	NEG IRR	NEG IRR	16.76%	54.79%	98.76%	142.92%
	550,000	NEG IRR	NEG IRR	-11.45%	24.32%	69.56%	118.12%	166.67%
	600,000	NEG IRR	NEG IRR	-4.18%	33.02%	84.47%	137.47%	190.42%

In summary, the geothermal vegetable drying plant is estimated to be unviable based on the current set of assumptions mainly due to the high OPEX values (including cost of goods sold). However, it is clear from the sensitivity analysis that the plant can be made viable by adopting cost cutting measures to minimize OPEX and/or sell the dried produce at higher prices.

2.4.4 ***Direct Use Geothermal Project:*** *MILK PASTEURIZATION (Retrofit)* ***Applicable Sites:*** *Karago*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of retrofitting a milk pasteurization plant with a 120,000 liter/day capacity to operate on geothermal heat is estimated at USD 178,500 (**Table 118**).

Table 118: Geothermal Milk Processing Retrofit Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	100,000
Pumps	3,500
Well Drilling	30,000
Pipes	45,000
Total CAPEX ($ USD)	**178,500**

- ***Operating Costs***

It is assumed that all the regular operating costs of the existing facility (except fuel costs which will be eliminated by the retrofit) will remain the same, while the annual O&M cost of the geothermal direct-use system and retrofits is estimated at 10% of project CAPEX – USD 17,850.

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal milk pasteurization to the cost of identified conventional milk pasteurization systems including diesel-fired and solar thermal plants. **Table 119** presents the results of the analysis showing the total annualized cost of each system.

Table 119: Milk Processing Energy Systems Cost Comparison

	MILK PROCESSING ENERGY SYSTEMS COST COMPARISON		
	Diesel	Solar Thermal	Geothermal
Total Heating Equipment Costs ($)	$100,000.00	$3,900,000.00	$178,500.00
Design Life - Heating Equipment (Yrs)	20	25	25
Annualized Capital Cost ($/Yr)	**$5,000.00**	**$156,000.00**	**$7,140.00**
Thermal Energy Requirement (MJ/Yr)	7,263,000.0	7,263,000.0	7,263,000.0
Density of Fuel (Kg/m3)	850.0	-	-
Calorific Value of Fuel (MJ/Kg)	44.8	-	-
Volume of Fuel Required (Ltr. or m3/Yr)	190,730.0	-	-
Fuel Costs ($/Ltr. or m3)	$1.07	$0.00	$0.00
Annual Op Costs - Fuel ($/Yr)	**$204,081.14**	**$0.00**	**$0.00**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$10,000.00**	**$390,000.00**	**$17,850.00**
Total Annualized Costs ($/Yr)	**$219,081.14**	**$546,000.00**	**$24,990.00**
Total Annual Costs Savings ($/Yr)	**$194,091.14**	**$521,010.00**	
Total Annual Costs Savings (%)	**89%**	**95%**	

The analysis found that geothermal direct-use has the least total annualized costs, followed by diesel and lastly solar thermal. Switching to geothermal energy will result in costs savings of 89% and 95% compared to diesel and solar thermal respectively. However, the sensitivity analysis presented in Table Z below shows that with a major increase in the CAPEX to USD 1.6 million, the geothermal option becomes costlier than diesel by 3%.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the milk processing retrofit project, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is very attractive with an after-tax equity IRR of 219.6%, payback period of 1 year and an after-tax project IRR of 80.58%. As shown in **Table 120**, the annual cost savings realized by the plant is USD 194,091. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 3.23 million while net cashflows to be distributed is USD 3.17 million.

Table 120: Geothermal Milk Processing Analysis Results

MILK PROCESSING RESULTS SUMMARY	
Annual Cost Savings	$194,091.14
Total CF to Equity	$3,226,955
Net CF to Equity	$3,173,405
Cash on Cash Return	59.26x
After Tax Equity IRR	219.60%
After Tax Project IRR	80.58%
Payback Year	1

- ***Sensitivity Analysis***

Table **121** shows the impact of increases in CAPEX at 100% intervals on the equity IRR, payback period, and cost savings. The results reveal that the milk processing plant retrofit will not be viable if CAPEX increases up to USD 892,500 and above at the production levels analyzed.

Table 121: Geothermal Milk Processing Sensitivity Analysis

		Equity IRR	Payback (Yrs)	Cost Savings ($/Yr)	Cost Savings (%)
CAPEX		219.60%	1	$194,091.14	89%
178,500	0%	219.60%	1	$194,091.14	89%
357,000	100%	75.97%	2	$169,101.14	77%
535,500	200%	29.84%	4	$144,111.14	66%
714,000	300%	12.49%	13	$119,121.14	54%
892,500	400%	3.76%	19	$94,131.14	43%
1,071,000	500%	-2.02%	NONE	$69,141.14	32%
1,249,500	600%	-6.91%	NONE	$44,151.14	20%
1,428,000	700%	-13.95%	NONE	$19,161.14	9%
1,606,500	800%	NEG IRR	NONE	-$5,828.86	-3%
1,785,000	900%	NEG IRR	NONE	-$30,818.86	-14%
1,963,500	1000%	NEG IRR	NONE	-$55,808.86	-25%

In conclusion, the geothermal milk processing plant retrofit project is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that increases in CAPEX will result in lower cost savings which would make the retrofit unviable.

2.5 TANZANIA

Geothermal Site	Categorized Direct Use Applications
Kiejo-Mbaka	1. Vegetable/grain drying 2. Fish drying 3. Milk pasteurization 4. Balneotherapy 5. Tea processing 6. Greenhouse heating

2.5.1 ***Direct Use Geothermal Project:*** *VEGETABLE/GRAIN DRYING (Greenfield)* ***Applicable Sites:*** *Kiejo-Mbaka*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal vegetable drying plant with a 1-ton/batch capacity is estimated at USD 272,094 (**Table 122**).

Table 122: Geothermal Vegetable Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Construction	60,000
Batch Dryer	65,000
Land Acquisition Cost	1,624.04
Blanching machine	3,000
Pre-cooling machine	30,000
Packaging equipment	10,970
Total CAPEX ($ USD)	**272,094**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 234,395 (**Table 123**).

Table 123: Geothermal Vegetable Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Cost of Fresh Veg (incl. Transport)	US$/Kg	0.26	142,915
Electricity Costs	US$/kwh	0.13	13,910
Equipment O&M	% of CAPEX	10.0%	27,209
Labor (Non-payroll)	US$/hr	0.63	13,225
Payroll	US$/Yr	N/A	16,067
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	1,451
Distribution/Marketing Expenses	% of Rev	0.5%	1,451
Utilities, Property Tax	US$/sqft	2.0	10,764
Packaging	US$/Kg	0.09	7,309
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**234,395**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of a geothermal vegetable drying plant to the cost of identified conventional vegetable drying systems including open air sun drying, solar drying and wood-fired drying systems. **Table 124** presents the results of the analysis showing the total annualized cost of each system.

Table 124: Vegetable Drying Energy Systems Cost Comparison

	VEGETABLE DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	5.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	300	600	600	600
Max Annual Capacity per Dryer (Kg)	1,500.0	600,000.0	600,000.0	600,000.0
Volume of Veg Processed per Year (Kg)	550,000	550,000	550,000	550,000
No. of Dryers Required	367.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$158,000.00	$226,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$22,020.00**	**$4,414.40**	**$7,900.00**	**$9,060.00**
Fuel Requirement (kg/Yr)	-	-	79,019.35	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.11	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$8,692.13**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.13	0.13
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$13,910.42**	**$13,910.42**
Annual Op Costs - Labour ($/Yr)	**$16,531.35**	**$13,225.08**	**$16,531.35**	**$13,225.08**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$11,010.00**	**$8,828.80**	**$15,800.00**	**$22,650.00**
Cost of Lost Revenue ($/Yr)	$145,109.25	-	-	-
Total Annualized Costs ($/Yr)	**$194,670.60**	**$26,468.28**	**$62,833.90**	**$58,845.50**
Total Annual Costs Savings ($/Yr)	**$135,825.10**	**-$32,377.22**	**$3,988.40**	
Total Annual Costs Savings (%)	**70%**	**-122%**	**6%**	

The analysis found that solar drying has the least total annualized costs, followed by geothermal direct-use, wood-fired dryers and open-air sun drying. Switching to geothermal energy will result in costs savings of 6% and 70% compared to wood-fired dryers and open-air sun drying respectively.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the vegetable drying application, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is attractive with an after-tax equity IRR of 19.36%, payback period of 9 years and an after-tax project IRR of 18.13%. As shown in **Table 125**, the average annual revenue generated by the plant is USD 325,811, while the average total annual expenses are USD 264,802. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 806,984, while net cashflows to be distributed is USD 725,356.

Table 125: Geothermal Vegetable Drying Analysis Results

VEGETABLE DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	78,178
Avg Annual Revenue	$325,810.56
Avg Annual Expenses	$264,802.05
Avg EBITDA	$61,008.51
Total CF to Equity	$806,984
Net CF to Equity	$725,356
Cash on Cash Return	8.89x
After Tax Equity IRR	19.36%
After Tax Project IRR	18.13%
Payback Year	9

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table **126** shows the impact of increases in CAPEX and the quantity of fresh vegetables processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the geothermal vegetable drying plant will not be viable if CAPEX increases by 40% and above at the production levels analyzed, except for the 600,000kg volume and 40% CAPEX increase scenario.

Table 126: Geothermal Vegetable Drying CAPEX Scenarios

		CAPEX						
		$163,256	$217,675	$272,094	$326,513	$380,932	$435,350	$489,769
	19.36%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	-1.70%	-10.89%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	350,000	8.55%	0.00%	-5.73%	-13.61%	NEG IRR	NEG IRR	NEG IRR
	400,000	18.88%	7.58%	0.98%	-3.72%	-8.38%	-15.40%	NEG IRR
	450,000	31.39%	15.16%	7.00%	1.62%	-2.39%	-5.79%	-10.22%
	500,000	46.08%	23.57%	13.06%	6.62%	2.07%	-1.44%	-4.42%
	550,000	61.75%	33.48%	19.36%	11.69%	6.35%	2.41%	-0.72%
	600,000	77.71%	44.53%	26.59%	16.75%	10.69%	6.15%	2.67%

  ✓ ***OPEX Scenarios***

Table 127 shows the impact of increases in OPEX and the quantity of fresh vegetable processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal vegetable drying plant will not be viable if OPEX increases by 20% and above at the production levels analyzed.

Table 127: Geothermal Vegetable Drying OPEX Scenarios

		OPEX						
		$140,637	$187,516	$234,395	$281,273	$328,152	$375,031	$421,910
	19.36%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	24.24%	6.15%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	350,000	36.69%	13.81%	-5.73%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	400,000	50.64%	22.07%	0.98%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	450,000	65.21%	31.87%	7.00%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	500,000	79.98%	42.94%	13.06%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	550,000	94.81%	54.71%	19.36%	-8.77%	NEG IRR	NEG IRR	NEG IRR
	600,000	109.66%	66.78%	26.59%	-2.35%	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 128 shows the impact of increases in the price of dried vegetables and the quantity of fresh vegetables processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results also reveal that the geothermal vegetable drying plant will not be viable if prices decrease by 20% and above at the production levels analyzed. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable if the quantity of fresh vegetables processed falls below 500,000kg.

Table 128: Geothermal Vegetable Drying Price Scenarios

		Price						
		$2.21	$2.95	$3.69	$4.43	$5.17	$5.90	$6.64
	19.36%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	NEG IRR	NEG IRR	NEG IRR	5.89%	23.69%	47.36%	73.88%
	350,000	NEG IRR	NEG IRR	-5.73%	14.74%	39.49%	70.04%	101.43%
	400,000	NEG IRR	NEG IRR	0.98%	24.63%	57.33%	93.09%	129.01%
	450,000	NEG IRR	NEG IRR	7.00%	36.54%	75.78%	116.18%	156.58%
	500,000	NEG IRR	NEG IRR	13.06%	49.80%	94.36%	139.27%	184.14%
	550,000	NEG IRR	NEG IRR	19.36%	63.64%	112.97%	162.35%	211.68%
	600,000	NEG IRR	NEG IRR	26.59%	77.68%	131.57%	185.42%	239.22%

In summary, the geothermal vegetable drying plant is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that a slight increase in CAPEX/OPEX or decrease in prices will make the plant unviable.

2.5.2 ***Direct Use Geothermal Project:*** *FISH DRYING (Greenfield)*
Applicable Sites: *Kiejo-Mbaka*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal fish drying plant with a 1-ton/batch capacity is estimated at USD 265,553 (**Table 129**).

Table 129: Geothermal Fish Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Constr. Of Drying Station	150,000
Drying Cabinet	2,000
Packaging equipment	10,970
Land Acquisition Cost	1,082.69
Total CAPEX ($ USD)	**265,553**

- ***Operating Costs***

Table 130 shows the operating costs for the first year of plant operation is estimated at USD 523,790. Cost of fresh fish estimated at USD 1.5/kg is based on Rwanda figures. It should be noted that the total operating costs would be much higher if the cost of freshwater fish is TSH 5,000 (USD 2.17) per kg as indicated during the stakeholder survey.

Table 130: Geothermal Fish Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	*Units*	Cost/Unit	1st Year (USD)
Cost of Fresh Fish (incl. Transport)	US$/Kg	1.50	450,000
Electricity Costs	US$/kwh	0.13	7,588
Equipment O&M	% of CAPEX	10.0%	26,555
Labor (Non-payroll)	US$/hr	0.63	11,336
Payroll	US$/Yr	N/A	16,067
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	2,752
Distribution/Marketing Expenses	% of Rev	0.5%	2,752
Utilities, Property Tax	US$/sqft	2.0	3,582
Packaging	US$/Kg	0.05	3,067
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**523,790**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal fish drying to the cost of identified conventional fish drying systems including open air sun drying, solar drying, and wood-fired systems. **Table 131** presents the results of the analysis showing the total annualized cost of each system.

Table 131: Fish Drying Energy Systems Cost Comparison

	FISH DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	10.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	150	300	300	300
Max Annual Capacity per Dryer (Kg)	1,500.0	300,000.0	300,000.0	300,000.0
Volume of Fish Processed per Year (Kg)	300,000	300,000	300,000	300,000
No. of Dryers Required	200.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$185,000.00	$253,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$12,000.00**	**$4,414.40**	**$9,250.00**	**$10,140.00**
Fuel Requirement (kg/Yr)	-	-	39,135.66	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.11	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$4,304.92**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.13	0.13
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$7,587.50**	**$7,587.50**
Annual Op Costs - Labour ($/Yr)	**$14,169.73**	**$11,335.78**	**$14,169.73**	**$11,335.78**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$6,000.00**	**$8,828.80**	**$18,500.00**	**$25,350.00**
Cost of Lost Revenue ($/Yr)	$275,220.00	-	-	-
Total Annualized Costs ($/Yr)	**$307,389.73**	**$24,578.98**	**$53,812.15**	**$54,413.28**
Total Annual Costs Savings ($/Yr)	**$252,976.44**	**-$29,834.30**	**-$601.13**	
Total Annual Costs Savings (%)	**82%**	**-121%**	**-1%**	

The analysis found that solar drying has the least total annualized costs, followed by wood-fired dryers, geothermal direct-use and open-air sun drying. Meanwhile, switching to geothermal energy will result in costs savings of 82% compared to open-air sun drying.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the fish drying application, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is unattractive with an after-tax equity IRR of 2.71%, payback period of 21 years and an after-tax project IRR of 7.72%. As shown in **Table 132**, the average annual revenue generated by the plant is USD 617,807, while the average total annual expenses are USD 591,740. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 180,929, while net cashflows to be distributed is USD 101,263.

Table 132: Geothermal Fish Drying Analysis Results

FISH DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	65,604
Avg Annual Revenue	$617,807
Avg Annual Expenses	$591,740
Avg EBITDA	$26,067
Total CF to Equity	$180,929
Net CF to Equity	$101,263
Cash on Cash Return	1.27x
After Tax Equity IRR	2.71%
After Tax Project IRR	7.72%
Payback Year	21

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 133 shows the impact of increases in CAPEX and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the geothermal fish drying plant will be viable if CAPEX decreases by 20% and above at the base case production level.

Table 133: Geothermal Fish Drying CAPEX Scenarios

		CAPEX						
		$159,332	$212,442	$265,553	$318,663	$371,774	$424,884	$477,995
	2.71%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	-5.43%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	0.69%	-7.83%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	225,000	6.15%	-2.26%	-9.60%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	11.60%	1.96%	-4.13%	-10.96%	NEG IRR	NEG IRR	NEG IRR
	275,000	17.08%	6.02%	-0.58%	-5.50%	-12.07%	NEG IRR	NEG IRR
	300,000	23.25%	10.11%	2.71%	-2.33%	-6.75%	-13.01%	NEG IRR

  ✓ ***OPEX Scenarios***

Table 134 shows the impact of increases in OPEX and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal fish drying plant will be viable if OPEX decreases by 20% and above at all the production levels analyzed.

Table 134: Geothermal Fish Drying OPEX Scenarios

		OPEX						
		$314,274	$419,032	$523,790	$628,548	$733,306	$838,064	$942,822
	2.71%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	59.02%	15.83%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	78.08%	24.44%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	97.27%	34.55%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	225,000	116.47%	45.78%	-9.60%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	135.67%	57.58%	-4.13%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	275,000	154.86%	69.60%	-0.58%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	300,000	174.04%	81.71%	2.71%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

  ✓ ***Price Scenarios***

Table 135 shows the impact of increases in the price of dry fish and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX. The results also reveal that the geothermal fish drying plant will be viable if prices increase by 20% at production levels of 175,000kg and above. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable at the production levels analyzed.

Table 135: Geothermal Fish Drying Price Scenarios

		Price						
		$5.00	$6.67	$8.34	$10.01	$11.67	$13.34	$15.01
Quantity (Kg)	2.71%	-40%	-20%	0%	20%	40%	60%	80%
	150,000	NEG IRR	NEG IRR	NEG IRR	4.22%	25.60%	54.57%	86.17%
	175,000	NEG IRR	NEG IRR	NEG IRR	10.77%	39.11%	75.34%	112.44%
	200,000	NEG IRR	NEG IRR	NEG IRR	17.36%	54.08%	96.30%	138.70%
	225,000	NEG IRR	NEG IRR	-9.60%	24.92%	69.58%	117.28%	164.95%
	250,000	NEG IRR	NEG IRR	-4.13%	33.59%	85.22%	138.25%	191.19%
	275,000	NEG IRR	NEG IRR	-0.58%	43.10%	100.90%	159.20%	217.42%
	300,000	NEG IRR	NEG IRR	2.71%	53.10%	116.58%	180.16%	243.65%

In conclusion, the geothermal fish drying plant is estimated to be unviable based on the current assumptions, particularly due to the relatively lower local price of dried fish. However, it is clear from the sensitivity analysis that the project can be made viable by exploring opportunities to decrease OPEX and/or increase prices.

2.5.3 ***Direct Use Geothermal Project:*** *MILK PASTEURIZATION (Retrofit)*
Applicable Sites: *Kiejo-Mbaka*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of retrofitting a milk pasteurization plant with a 120,000 liter/day capacity to operate on geothermal heat is estimated at USD 178,500 (**Table 136**).

Table 136: Geothermal Milk Processing Retrofit Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	100,000
Pumps	3,500
Well Drilling	30,000
Pipes	45,000
Total CAPEX ($ USD)	**178,500**

- ***Operating Costs***

It is assumed that all the regular operating costs of the existing facility (except fuel costs which will be eliminated by the retrofit) will remain the same, while the annual O&M cost of the geothermal direct-use system and retrofits is estimated at 10% of project CAPEX – USD 17,850.

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal milk pasteurization to the cost of identified conventional milk pasteurization systems including diesel-fired and solar thermal plants. **Table 137** presents the results of the analysis showing the total annualized cost of each system.

Table 137: Milk Processing Energy Systems Cost Comparison

	MILK PROCESSING ENERGY SYSTEMS COST COMPARISON		
	Diesel	Solar Thermal	Geothermal
Total Heating Equipment Costs ($)	$100,000.00	$3,900,000.00	$178,500.00
Design Life - Heating Equipment (Yrs)	20	25	25
Annualized Capital Cost ($/Yr)	**$5,000.00**	**$156,000.00**	**$7,140.00**
Thermal Energy Requirement (MJ/Yr)	7,263,000.0	7,263,000.0	7,263,000.0
Density of Fuel (Kg/m3)	850.0	-	-
Calorific Value of Fuel (MJ/Kg)	44.8	-	-
Volume of Fuel Required (Ltr. or m3/Yr)	190,730.0	-	-
Fuel Costs ($/Ltr. or m3)	$0.82	$0.00	$0.00
Annual Op Costs - Fuel ($/Yr)	**$157,161.55**	**$0.00**	**$0.00**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$10,000.00**	**$390,000.00**	**$17,850.00**
Total Annualized Costs ($/Yr)	**$172,161.55**	**$546,000.00**	**$24,990.00**
Total Annual Costs Savings ($/Yr)	**$147,171.55**	**$521,010.00**	
Total Annual Costs Savings (%)	**85%**	**95%**	

The analysis found that geothermal direct-use has the least total annualized costs, followed by diesel and lastly solar thermal. Switching to geothermal energy will result in costs savings of 85% and 95% compared to diesel and solar thermal, respectively. However, the sensitivity analysis presented below shows that with a major increase in the CAPEX to USD 1.2 million, the geothermal option becomes costlier than diesel by 2%.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the milk processing retrofit project, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is very attractive with an after-tax equity IRR of 157.9%, payback period of 1 year and an after-tax project IRR of 62.12%. As shown in **Table 138**, the annual cost savings realized by the plant is USD 147,172. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 2.4 million while net cashflows to be distributed is USD 2.35 million.

Table 138: Geothermal Milk Processing Retrofit Analysis Results

MILK PROCESSING RESULTS SUMMARY	
Annual Cost Savings	$147,171.55
Total CF to Equity	$2,404,500
Net CF to Equity	$2,350,950
Cash on Cash Return	43.90x
After Tax Equity IRR	157.93%
After Tax Project IRR	62.12%
Payback Year	1

- ***Sensitivity Analysis***

Table 139 shows the impact of increases in CAPEX at 100% intervals on the equity IRR, payback period, and cost savings. The results reveal that the milk processing plant retrofit will not be viable if CAPEX increases up to USD 714k and above at the production levels analyzed.

Table 139: Geothermal Milk Processing Retrofit Sensitivity Analysis

		Equity IRR	Payback (Yrs)	Cost Savings ($/Yr)	Cost Savings (%)
CAPEX		157.93%	1	$147,171.55	85%
178,500	0%	157.93%	1	$147,171.55	85%
357,000	100%	45.31%	3	$122,181.55	71%
535,500	200%	14.49%	12	$97,191.55	56%
714,000	300%	3.06%	20	$72,201.55	42%
892,500	400%	-3.84%	NONE	$47,211.55	27%
1,071,000	500%	-11.04%	NONE	$22,221.55	13%
1,249,500	600%	NEG IRR	NONE	-$2,768.45	-2%
1,428,000	700%	NEG IRR	NONE	-$27,758.45	-16%
1,606,500	800%	NEG IRR	NONE	-$52,748.45	-31%
1,785,000	900%	NEG IRR	NONE	-$77,738.45	-45%
1,963,500	1000%	NEG IRR	NONE	-$102,728.45	-60%

In summary, the geothermal milk processing plant retrofit project is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that increases in CAPEX will result in lower cost savings which would make the retrofit unviable.

2.5.4 ***Direct Use Geothermal Project:*** *BALNEOTHERAPY / GEOTHERMAL SPA (Greenfield)* ***Applicable Sites:*** *Kiejo-Mbaka*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal spa with a 1,000-person/use capacity is estimated at USD 890,362 (**Table 140**).

Table 140: Geothermal Spa Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	10,500
Well Drilling & Pipes	565,000
Constr. Of Spa	286,200
Land Acquisition Cost	8,662
Total CAPEX ($ USD)	**890,362**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 136,602 (**Table 141**).

Table 141: Geothermal Spa Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Towel Supply and Laundry Costs	US$/Unit	3.38	3,380
Electricity Costs	US$/kwh	0.13	7,489
Equipment O&M	% of CAPEX	10.0%	89,036
Labor (Non-payroll)	US$/hr	0.63	14,918
Payroll	US$/Yr	N/A	16,067
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	657
Marketing Expenses	% of Rev	0.5%	657
Spa Building Utility Costs	US$/sqft	2.0	4,306
Opex Annual Inflator (%)		1%	
TOTAL OPEX			136,602

Cost Comparison

Balneotherapy is based on hot brine provided by geothermal resources only, hence, a cost comparison is not applicable.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the geothermal spa, based on the assumptions detailed in **Annex 1**, found that the project is unviable with a negative IRR as the cashflows projected to be generated over the life of the spa at the assumed level of ticket sales will be insufficient to pay back the initial investment. As shown in **Table 142**, the average annual revenue generated by the spa of USD 148,431 is less than the projected average annual expenses projected of USD 154,323. The total loss to be incurred by investors over the life of the plant is estimated at USD 1.75 million.

Table 142: Geothermal Spa Analysis Results

GEOTHERMAL SPA RESULTS SUMMARY	
Avg Annual Sales (Tickets)	14,000
Avg Annual Revenue	$148,431.01
Avg Annual Expenses	$154,322.79
Avg EBITDA	#DIV/0!
Total CF to Equity	-$1,480,286
Net CF to Equity	-$1,747,394
Cash on Cash Return	-6.54x
After Tax Equity IRR	NEG IRR
After Tax Project IRR	#NUM!
Payback Year	#N/A

- ***Sensitivity Analysis***
    - ✓ ***CAPEX Scenarios***

Table 143 shows the impact of increases in CAPEX and the number of spa visitors at 20% and 5,000 intervals respectively on the equity IRR. The results show that the geothermal spa will still not be viable at the assumed level of ticket sales even if CAPEX decreases by 40%. However, the spa will be moderately viable if the annual number of visitors increase to 35,000 and above even if CAPEX increases by 20%.

Table 143: Geothermal Spa CAPEX Scenarios

		CAPEX						
		$534,217	$712,289	$890,362	$1,068,434	$1,246,506	$1,424,578	$1,602,651
# of Visitors	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
	5,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	10,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	15,000	-0.17%	-7.78%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	20,000	11.11%	2.14%	-3.50%	-8.85%	NEG IRR	NEG IRR	NEG IRR
	25,000	23.15%	10.59%	3.51%	-1.26%	-5.06%	-9.43%	NEG IRR
	30,000	38.32%	19.28%	10.27%	4.42%	0.26%	-3.07%	-6.01%
	35,000	55.58%	29.66%	17.11%	10.05%	5.06%	1.36%	-1.62%

✓ ***OPEX Scenarios***

Table 144 shows the impact of increases in OPEX and the number of spa visitors at 20% and 5,000 intervals respectively on the equity IRR. The results show that the equity IRR is less sensitive to changes in OPEX than CAPEX. The results show that the geothermal spa will still not be viable at the assumed level of ticket sales even if OPEX decreases by 40%. However, the spa will be moderately viable if the annual number of visitors increase to 35,000 and above even if OPEX increases by 20%.

Table 144: Geothermal Spa OPEX Scenarios

		OPEX						
		$81,961	$109,281	$136,602	$163,922	$191,242	$218,563	$245,883
# of Visitors	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
	5,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	10,000	-11.94%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	15,000	-0.98%	-6.25%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	20,000	6.15%	1.48%	-3.50%	-11.67%	NEG IRR	NEG IRR	NEG IRR
	25,000	13.30%	8.37%	3.51%	-1.44%	-7.69%	NEG IRR	NEG IRR
	30,000	20.84%	15.35%	10.27%	5.18%	0.13%	-5.52%	NEG IRR
	35,000	29.71%	23.03%	17.11%	11.81%	6.51%	1.31%	-4.32%

✓ ***Price Scenarios***

Table 145 shows the impact of increases in the spa ticket price and the number of spa visitors at 20% and 5,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results show that the geothermal spa will still not be viable at the assumed level of ticket sales even if prices increase by up to 80%. However, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the spa will be viable if the annual number of visitors increase to 30,000 and above.

Table 145: Geothermal Spa Price Scenarios

		Price						
		$5.67	$7.57	$9.46	$11.35	$13.24	$15.13	$17.02
# of Visitors	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
	5,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	10,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	-10.89%	-5.17%
	15,000	NEG IRR	NEG IRR	NEG IRR	-6.24%	-0.96%	3.61%	8.13%
	20,000	NEG IRR	NEG IRR	-3.50%	2.82%	8.84%	14.92%	21.50%
	25,000	NEG IRR	-4.44%	3.51%	11.09%	18.86%	27.99%	38.55%
	30,000	-11.48%	1.20%	10.27%	19.64%	30.95%	44.13%	58.27%
	35,000	-4.57%	6.40%	17.11%	29.85%	45.20%	61.79%	78.75%

In summary, the geothermal spa is estimated to be unviable based on the current set of assumptions especially the assumption that the spa will receive only 14,000 visitors a year based on available information on the Olkaria geothermal spa in Kenya.[10] However, it is clear from the sensitivity analysis that the spa can be made viable by devising and implementing strategies to increase the number of tickets sold annually.

2.5.5 ***Direct Use Geothermal Project:*** *TEA PROCESSING (Retrofit)*
Applicable Sites: *Kiejo-Mbaka*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of retrofitting a tea drying plant, producing 2,000 tons of processed tea per year, to operate on geothermal heat is estimated at USD 118,500 (**Table 146**).

Table 146: Geothermal Tea Drying Plant Retrofit Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	40,000
Pumps	3,500
Well Drilling	30,000
Pipes	45,000
Total CAPEX ($ USD)	**118,500**

- ***Operating Costs***

It is assumed that all the regular operating costs of the existing facility (except fuel costs which will be eliminated by the retrofit and reduced labor costs) will remain the same, while the annual O&M cost of the geothermal direct-use system and retrofits is estimated at 10% of project CAPEX - $11,850.

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal tea drying to the cost of identified conventional tea drying systems including diesel-fired and wood-fired dryers. **Table 147** presents the results of the analysis showing the total annualized cost of each system.

[10] Mangi, P., "Project Review of Geothermal Spa Construction in Kenya and Iceland," Kenya Electricity Generating Company Ltd. (KenGen), United Nations University Geothermal Training Programme, (2015): https://orkustofnun.is/gogn/unu-gtp-report/UNU-GTP-2015-21.pdf

Table 147: Tea Drying Energy Systems Cost Comparison

	TEA DRYING ENERGY SYSTEMS COST COMPARISON		
	Diesel	Wood	Geothermal
Output per Batch per Dryer (Kg)	1,722.9	1,722.9	1,722.9
No. of Batches per Year per Dryer	600	600	600
Annual Output per Dryer (Kg)	1,033,738.8	1,033,738.8	1,033,738.8
Volume of Processed Tea per Year (Kg)	2,067,478	2,067,478	2,067,478
No. of Dryers Required	2.0	2.0	2.0
Heating Equipment Costs per Dryer ($)	$20,000.00	$30,000.00	$118,500.00
Design Life - Heating Equipment (Yrs)	20	20	25
Annualized Capital Cost ($/Yr)	**$2,000.00**	**$3,000.00**	**$4,740.00**
Fuel Requirement (kWh/Kg)	5.50	5.50	-
Fuel Costs ($/kWh)	$0.08	$0.02	$0.00
Annual Op Costs - Fuel ($/Yr)	**$909,690.12**	**$204,680.28**	**$0.00**
Electricity Requirement (kWh/Kg)	1.00	1.00	1.00
Electricity Cost ($/kWh)	$0.15	$0.15	$0.15
Annual Op Costs - Electricity ($/Yr)	**$310,121.63**	**$310,121.63**	**$310,121.63**
Plant Labor Required per Dryer	30.00	40.00	30.00
Total Plant Labor Required	60.00	80.00	60.00
Labor Costs ($/hr)	$0.63	$0.63	$0.63
No. of Drying Days per Year	300.00	300.00	300.00
Annual Op Costs - Labour ($/Yr)	**$226,715.63**	**$302,287.51**	**$226,715.63**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$4,000.00**	**$6,000.00**	**$11,850.00**
Cost of Lost Revenue ($/Yr)	-	-	-
Other Costs ($/Yr)	-	-	-
Total Annualized Costs ($/Yr)	**$1,452,527.39**	**$826,089.42**	**$553,427.27**
Total Annual Costs Savings ($/Yr)	**$899,100.12**	**$272,662.16**	
Total Annual Costs Savings (%)	**62%**	**33%**	

The analysis found that geothermal direct-use has the least total annualized costs, followed by firewood and diesel. Switching to geothermal energy will result in costs savings of 33% and 62% compared to wood and diesel respectively, mainly due to the avoided fuel expenditure. However, the sensitivity analysis presented below shows that with a major increase in the CAPEX to USD 2.3 million, the geothermal option becomes costlier than wood by 3%.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the tea drying plant retrofit project, based on the assumptions detailed in **Annex 1,** found that the investment opportunity is very attractive with an after-tax equity IRR of 483.85%, payback period of 1 year and an after-tax project IRR of 168.75%. As shown in **Table 148**, the annual cost savings realized by the plant is USD 272,662. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 4.28 million while net cashflows to be distributed is USD 4.24 million.

Table 148: Geothermal Tea Drying Plant Retrofit Analysis Results

TEA PROCESSING RESULTS SUMMARY	
Annual Cost Savings	$272,662.16
Total CF to Equity	$4,275,099
Net CF to Equity	$4,239,549
Cash on Cash Return	119.26x
After Tax Equity IRR	483.85%
After Tax Project IRR	168.75%
Payback Year	1

- ***Sensitivity Analysis***

Table 149 shows the impact of increases in CAPEX at 200% intervals on the equity IRR, payback period, and cost savings. The results reveal that the tea processing plant retrofit will not be viable if CAPEX increases up to USD 1.3 million and above.

Table 149: Geothermal Tea Drying Plant Retrofit Sensitivity Analysis

		Equity IRR	Payback (Yrs)	Cost Savings ($/Yr)	Cost Savings (%)
CAPEX		483.85%	1	$272,662.16	33%
118,500	0%	483.85%	1	$272,662.16	33%
355,500	200%	117.56%	1	$239,482.16	29%
592,500	400%	52.47%	2	$206,302.16	25%
829,500	600%	28.60%	4	$173,122.16	21%
1,066,500	800%	16.73%	8	$139,942.16	17%
1,303,500	1000%	9.38%	13	$106,762.16	13%
1,540,500	1200%	3.57%	18	$73,582.16	9%
1,777,500	1400%	-2.97%	NONE	$40,402.16	5%
2,014,500	1600%	-14.89%	NONE	$7,222.16	1%
2,251,500	1800%	NEG IRR	NONE	-$25,957.84	-3%
2,488,500	2000%	NEG IRR	NONE	-$59,137.84	-7%

In summary, the geothermal tea processing plant retrofit project is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that increases in CAPEX will result in lower cost savings which would make the retrofit unviable.

2.5.6 ***Direct Use Geothermal Project:*** *GREENHOUSE HEATING (Retrofit)* ***Applicable Sites:*** *Kiejo-Mbaka*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of retrofitting an existing 8mx30m greenhouse in Kiejo-Mbaka to operate on geothermal heat is estimated at USD 118,500 (**Table 150**).

Table 150: Geothermal Greenhouse Retrofit Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	40,000
Pumps	3,500
Well Drilling	30,000
Pipes	45,000
Total CAPEX ($ USD)	**118,500**

- ***Operating Costs***

It is assumed that all the regular operating costs of the existing facility (except fuel costs which will be eliminated by the retrofit) will remain the same, while the annual O&M cost of the geothermal direct-use system and retrofits is estimated at 10% of project CAPEX – USD 11,850.

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal greenhouse heating to the cost of identified conventional greenhouse heating systems including fuel oil and LPG-fueled systems. **Table 151** presents the results of the analysis showing the total annualized cost of each system.

Table 151: Greenhouse Heating Systems Cost Comparison

	GREENHOUSE HEATING SYSTEMS COST COMPARISON		
	Fuel Oil	LPG	Geothermal
Total Heating Equipment Costs ($)	$40,000.00	$40,000.00	$118,500.00
Design Life - Heating Equipment (Yrs)	20	20	25
Annualized Capital Cost ($/Yr)	**$2,000.00**	**$2,000.00**	**$4,740.00**
Thermal Energy Requirement (MJ/Yr)	1,149,070.7	1,149,070.7	1,149,070.7
Calorific Value of Fuel (MJ/Kg)	41.5	46.3	-
Volume of Fuel Required (Kg/Yr)	27,688.5	24,817.9	-
Fuel Costs ($/Kg)	$0.54	$1.19	$0.00
Annual Op Costs - Fuel ($/Yr)	**$14,951.76**	**$29,533.35**	**$0.00**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$4,000.00**	**$4,000.00**	**$11,850.00**
Total Annualized Costs ($/Yr)	**$20,951.76**	**$35,533.35**	**$16,590.00**
Total Annual Costs Savings ($/Yr)	**$4,361.76**	**$18,943.35**	
Total Annual Costs Savings (%)	**21%**	**53%**	

The analysis found that geothermal direct-use has the least total annualized costs, followed by fuel oil and LPG. Switching to geothermal energy will result in costs savings of 21% and 53% compared to fuel oil and LPG, respectively, mainly due to the avoided fuel expenditure. However, the sensitivity analysis presented below shows that with a slight increase in the CAPEX to USD 260k, the geothermal option becomes costlier than LPG by 3%.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the greenhouse retrofit project, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is moderate with an after-tax equity IRR of 11.42%, payback period of 13 years and an after-tax project IRR of 13.88%. As shown in **Table 152**, the annual cost savings realized by the plant is USD 18,943. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 217,986 while net cashflows to be distributed is USD 182,436 million.

Table 152: Geothermal Greenhouse Retrofit Analysis Results

GREENHOUSE HEATING RESULTS SUMMARY	
Annual Cost Savings	$18,943.35
Total CF to Equity	$217,986
Net CF to Equity	$182,436
Cash on Cash Return	5.13x
After Tax Equity IRR	11.42%
After Tax Project IRR	13.88%
Payback Year	13

- ***Sensitivity Analysis***

Table 153 shows the impact of increases in CAPEX at 20% intervals on the equity IRR, payback period, and cost savings. The results reveal that the greenhouse retrofit will not be viable if CAPEX increases slightly by 20% at the greenhouse size analyzed.

Table 153: Geothermal Greenhouse Retrofit Sensitivity Analysis

		Equity IRR	Payback (Yrs)	Cost Savings ($/Yr)	Cost Savings (%)
CAPEX		11.42%	13	$18,943.35	53%
71,100	-40%	49.28%	3	$25,579.35	72%
94,800	-20%	23.16%	6	$22,261.35	63%
118,500	0%	11.42%	13	$18,943.35	53%
142,200	20%	4.28%	19	$15,625.35	44%
165,900	40%	-0.70%	NONE	$12,307.35	35%
189,600	60%	-4.69%	NONE	$8,989.35	25%
213,300	80%	-9.22%	NONE	$5,671.35	16%
237,000	100%	NEG IRR	NONE	$2,353.35	7%
260,700	120%	NEG IRR	NONE	-$964.65	-3%
284,400	140%	NEG IRR	NONE	-$4,282.65	-12%
308,100	160%	NEG IRR	NONE	-$7,600.65	-21%

In conclusion, the greenhouse retrofit project is estimated to be fairly viable based on the current assumptions. However, it is clear from the sensitivity analysis that a slight increase in CAPEX will make the project unviable. It is worth noting that the viability of the project has a direct correlation to the size of the greenhouse and thermal energy requirement.

2.6 UGANDA

Geothermal Site	Categorized Direct Use Applications
Kibiro	1. Vegetable/grain drying 2. Balneotherapy
Buranga	1. Fish drying 2. Tea processing 3. Balneotherapy
Panyimur	1. Fruit drying 2. Tea processing 3. Rice drying 4. Fish drying

2.6.1 ***Direct Use Geothermal Project:*** *VEGETABLE/GRAIN DRYING (Greenfield)* ***Applicable Sites:*** *Kibiro, Panyimur*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal vegetable drying plant with a 1-ton/batch capacity is estimated at USD 272,479 (**Table 154**).

Table 154: Geothermal Vegetable Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Construction	60,000
Batch Dryer	65,000
Land Acquisition Cost	2,009.48
Blanching machine	3,000
Pre-cooling machine	30,000
Packaging equipment	10,970
Total CAPEX ($ USD)	**272,479**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 286,488 (**Table 155**).

Table 155: Geothermal Vegetable Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Cost of Fresh Veg (incl. Transport)	US$/Kg	0.34	186,360
Electricity Costs	US$/kwh	0.16	17,151
Equipment O&M	% of CAPEX	10.0%	27,248
Labor (Non-payroll)	US$/hr	0.77	16,224
Payroll	US$/Yr	N/A	18,438
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	1,451
Distribution/Marketing Expenses	% of Rev	0.5%	1,451
Utilities, Property Tax	US$/sqft	2.0	10,764
Packaging	US$/Kg	0.09	7,309
Opex Annual Inflator (%)		1%	
TOTAL OPEX			286,488

Cost Comparison

A cost comparison analysis was conducted to compare the cost of a geothermal vegetable drying plant to the cost of identified conventional vegetable drying systems including open air sun drying, solar drying and wood-fired drying systems. **Table 156** presents the results of the analysis showing the total annualized cost of each system.

Table 156: Vegetable Drying Energy Systems Cost Comparison

	VEGETABLE DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	5.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	300	600	600	600
Max Annual Capacity per Dryer (Kg)	1,500.0	600,000.0	600,000.0	600,000.0
Volume of Veg Processed per Year (Kg)	550,000	550,000	550,000	550,000
No. of Dryers Required	367.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$158,000.00	$226,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$22,020.00**	**$4,414.40**	**$7,900.00**	**$9,060.00**
Fuel Requirement (kg/Yr)	-	-	79,019.35	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.18	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$14,223.48**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.16	0.16
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$17,151.11**	**$17,151.11**
Annual Op Costs - Labour ($/Yr)	**$20,279.39**	**$16,223.51**	**$20,279.39**	**$16,223.51**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$11,010.00**	**$8,828.80**	**$15,800.00**	**$22,650.00**
Cost of Lost Revenue ($/Yr)	$145,109.25	-	-	-
Total Annualized Costs ($/Yr)	**$198,418.64**	**$29,466.71**	**$75,353.99**	**$65,084.63**
Total Annual Costs Savings ($/Yr)	**$133,334.02**	**-$35,617.91**	**$10,269.36**	
Total Annual Costs Savings (%)	**67%**	**-121%**	**14%**	

The analysis showed that solar drying has the least total annualized costs, followed by geothermal direct-use, wood-fired dryers and open-air sun drying. Switching to geothermal energy will result in costs savings of 14% and 67% compared to wood-fired dryers and open-air sun drying, respectively.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the vegetable drying application, based on the assumptions detailed in **Annex 1**, found that the project is unviable with a negative IRR as the cashflows projected to be generated over the life of the plant at the assumed production level will be insufficient to pay back the initial investment. As shown in **Table 157**, the average annual revenue generated by the plant of USD 325,811 is only slightly higher than the projected average annual expenses of USD 323,653. The total loss to be incurred by investors over the life of the plant is estimated at USD 541,291.

Table 157: Geothermal Vegetable Drying Analysis Results Summary

VEGETABLE DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	78,178
Avg Annual Revenue	$325,810.56
Avg Annual Expenses	$323,653.76
Avg EBITDA	$2,156.80
Total CF to Equity	-$449,547
Net CF to Equity	-$531,291
Cash on Cash Return	-6.50x
After Tax Equity IRR	NEG IRR
After Tax Project IRR	-12.32%
Payback Year	#N/A

- ***Sensitivity Analysis***

✓ ***CAPEX Scenarios***

Table 158 shows the impact of increases in CAPEX and the quantity of fresh vegetables processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the geothermal vegetable drying plant will not be viable at the production levels analyzed even if CAPEX decreases by 40%.

Table 158: Geothermal Vegetable Drying CAPEX Scenarios

		CAPEX						
		$163,488	$217,984	$272,479	$326,975	$381,471	$435,967	$490,463
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	350,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	400,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	450,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	500,000	-7.59%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	550,000	-0.95%	-8.22%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	600,000	4.67%	-2.86%	-8.62%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

✓ ***OPEX Scenarios***

Table 159 shows the impact of increases in OPEX and the quantity of fresh vegetable processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal vegetable drying plant will be viable at the base case production level if OPEX decreases by 20%.

Table 159: Geothermal Vegetable Drying OPEX Scenarios

		OPEX						
		$171,893	$229,191	$286,488	$343,786	$401,084	$458,381	$515,679
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	9.77%	-11.47%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	350,000	17.44%	-3.45%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	400,000	26.18%	1.83%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	450,000	36.63%	6.95%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	500,000	48.31%	12.45%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	550,000	60.59%	18.16%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	600,000	73.11%	24.56%	-8.62%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 160 shows the impact of increases in the price of dried vegetables and the quantity of fresh vegetables processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX. The results also reveal that the geothermal vegetable drying plant will be viable at the current production level if prices increase by 20%. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable at the production levels analyzed.

Table 160: Geothermal Vegetable Drying Price Scenarios

		Price						
		$2.21	$2.95	$3.69	$4.43	$5.17	$5.90	$6.64
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	300,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	3.29%	19.31%	40.82%
	350,000	NEG IRR	NEG IRR	NEG IRR	-6.59%	11.85%	34.12%	63.84%
	400,000	NEG IRR	NEG IRR	NEG IRR	-0.13%	21.25%	52.09%	87.63%
	450,000	NEG IRR	NEG IRR	NEG IRR	5.63%	32.77%	71.21%	111.54%
	500,000	NEG IRR	NEG IRR	NEG IRR	11.73%	46.30%	90.59%	135.44%
	550,000	NEG IRR	NEG IRR	NEG IRR	18.16%	60.79%	110.01%	159.32%
	600,000	NEG IRR	NEG IRR	-8.62%	25.45%	75.61%	129.42%	183.20%

In summary, the geothermal vegetable drying plant is estimated to be unviable based on the current set of assumptions mainly due to the high OPEX values (including cost of goods sold). However, it is clear from the sensitivity analysis that the plant can be made viable by adopting cost cutting measures to minimize OPEX and/or sell the dried produce at higher prices.

2.6.2 ***Direct Use Geothermal Project:*** *BALNEOTHERAPY / GEOTHERMAL SPA (Greenfield)* ***Applicable Sites:*** *Kibiro, Buranga*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal spa with a 1,000-person/use capacity is estimated at USD 892,417 (**Table 161**).

Table 161: Geothermal Spa Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	10,500
Well Drilling & Pipes	565,000
Constr. Of Spa	286,200
Land Acquisition Cost	10,717
Total CAPEX ($ USD)	**892,417**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 144,305 (**Table 162**).

Table 162: Geothermal Spa Annual Operating Cost Estimates

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Towel Supply and Laundry Costs	US$/Unit	3.38	3,380
Electricity Costs	US$/kwh	0.16	9,234
Equipment O&M	% of CAPEX	10.0%	89,242
Labor (Non-payroll)	US$/hr	0.77	18,300
Payroll	US$/Yr	N/A	18,438
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	657
Marketing Expenses	% of Rev	0.5%	657
Spa Building Utility Costs	US$/sqft	2.0	4,306
Opex Annual Inflator (%)		1%	-
TOTAL OPEX			144,305

Cost Comparison

Balneotherapy is based on hot brine provided by geothermal resources only, hence, a cost comparison is not applicable.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the geothermal spa, based on the assumptions detailed in **Annex 1**, found that the project is unviable with a negative IRR as the cashflows projected to be generated over the life of the spa at the assumed level of ticket sales will be insufficient to pay back the initial investment. As shown in **Table 163**, the average annual revenue generated by the spa of USD 148,431 is less than the projected average annual expenses of USD 163,026. The total loss to be incurred by investors over the life of the plant is estimated at USD 2.28 million (higher than other countries analyzed for Spa due to high cost of debt).

Table 163: Geothermal Spa Analysis Results

GEOTHERMAL SPA RESULTS SUMMARY	
Avg Annual Sales (Tickets)	14,000
Avg Annual Revenue	$148,431.01
Avg Annual Expenses	$163,025.63
Avg EBITDA	#DIV/0!
Total CF to Equity	-$2,013,807
Net CF to Equity	-$2,281,532
Cash on Cash Return	-8.52x
After Tax Equity IRR	NEG IRR
After Tax Project IRR	#NUM!
Payback Year	#N/A

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 164 shows the impact of increases in CAPEX and the number of spa visitors at 20% and 5,000 intervals respectively on the equity IRR. The results show that the geothermal spa will still not be viable at the assumed level of ticket sales even if CAPEX decreases by 40%. However, the spa will be moderately viable if the annual number of visitors increase to 35,000 and above, if CAPEX remains unchanged.

Table 164: Geothermal Spa CAPEX Scenarios

		CAPEX						
		$535,450	$713,934	$892,417	$1,070,901	$1,249,384	$1,427,868	$1,606,351
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
# of Visitors	5,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	10,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	15,000	-4.33%	-13.08%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	20,000	5.49%	-1.82%	-6.91%	-13.45%	NEG IRR	NEG IRR	NEG IRR
	25,000	15.85%	5.38%	-0.41%	-4.59%	-8.32%	-13.64%	NEG IRR
	30,000	27.92%	13.04%	5.31%	0.51%	-3.08%	-6.11%	-9.35%
	35,000	43.14%	21.33%	11.35%	5.27%	1.17%	-2.00%	-4.68%

  ✓ ***OPEX Scenarios***

Table 165 shows the impact of increases in OPEX and the number of spa visitors at 20% and 5,000 intervals respectively on the equity IRR. The results show that the equity IRR is less sensitive to changes in OPEX than CAPEX. The results show that the geothermal spa will still not be viable at the assumed level of ticket sales even if OPEX decreases by 40%. However, the spa will be moderately viable if the annual number of visitors increase to 35,000 and above, if OPEX remains unchanged.

Table 165: Geothermal Spa OPEX Scenarios

		OPEX						
		$86,583	$115,444	$144,305	$173,166	$202,027	$230,888	$259,749
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
# of Visitors	5,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	10,000	-15.64%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	15,000	-3.70%	-9.68%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	20,000	2.61%	-1.81%	-6.91%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	25,000	8.81%	4.15%	-0.41%	-5.42%	-15.33%	NEG IRR	NEG IRR
	30,000	15.59%	10.28%	5.31%	0.59%	-4.47%	-13.02%	NEG IRR
	35,000	22.87%	16.89%	11.35%	6.12%	1.20%	-3.99%	-12.27%

  ✓ ***Price Scenarios***

Table 166 shows the impact of increases in the spa ticket price and the number of spa visitors at 20% and 5,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results show that the geothermal spa will still not be viable at the assumed level of ticket sales even if prices increase by up to 80%. However, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the spa will be viable if the annual number of visitors increase to 35,000 and above.

Table 166: Geothermal Spa Price Scenarios

		Price						
		$5.67	$7.57	$9.46	$11.35	$13.24	$15.13	$17.02
# of Visitors	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
	5,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	10,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	-8.34%
	15,000	NEG IRR	NEG IRR	NEG IRR	-10.22%	-4.22%	0.01%	3.96%
	20,000	NEG IRR	NEG IRR	-6.91%	-0.88%	4.41%	9.86%	15.76%
	25,000	NEG IRR	-8.26%	-0.41%	6.20%	13.30%	20.91%	29.95%
	30,000	NEG IRR	-2.70%	5.31%	13.81%	23.18%	34.73%	48.06%
	35,000	-9.11%	1.83%	11.35%	22.05%	35.45%	51.19%	67.88%

In summary, the geothermal spa is estimated to be unviable based on the current set of assumptions especially the assumption that the spa will receive only 14,000 visitors a year based on available information on the Olkaria geothermal spa in Kenya.[11] However, it is clear from the sensitivity analysis that the spa can be made viable by devising and implementing strategies to increase the number of tickets sold annually.

2.6.3 ***Direct Use Geothermal Project:*** *FISH DRYING (Greenfield)*
Applicable Sites: *Buranga, Panyimur*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal fish drying plant with a 1-ton/batch capacity is estimated at USD 265,810 (**Table 167**).

Table 167: Geothermal Fish Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Constr. Of Drying Station	150,000
Drying Cabinet	2,000
Packaging equipment	10,970
Land Acquisition Cost	1,339.65
Total CAPEX ($ USD)	**265,810**

- ***Operating Costs***

The operating costs for the first year of plant operation are estimated at USD 530,903 (**Table 168**).[12]

Table 168: Geothermal Fish Drying Plant Annual Operating Cost Estimates

[11] Mangi, P., "Project Review of Geothermal Spa Construction in Kenya and Iceland," Kenya Electricity Generating Company Ltd. (KenGen), United Nations University Geothermal Training Programme, (2015): https://orkustofnun.is/gogn/unu-gtp-report/UNU-GTP-2015-21.pdf

[12] The cost of fresh fish estimated at USD 1.5/kg is based on Rwanda figures. It should be noted that the total operating costs would be much higher if the cost of freshwater fish is UGX 15,000 ($4.07) per kg as indicated during the stakeholder survey.

OPERATING EXPENSES	Units	Cost/Unit	1st Year (USD)
Cost of Fresh Fish (incl. Transport)	US$/Kg	1.50	450,000
Electricity Costs	US$/kwh	0.16	9,355
Equipment O&M	% of CAPEX	10.0%	26,581
Labor (Non-payroll)	US$/hr	0.77	13,906
Payroll	US$/Yr	N/A	18,438
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	2,941
Distribution/Marketing Expenses	% of Rev	0.5%	2,941
Utilities, Property Tax	US$/sqft	2.0	3,582
Packaging	US$/Kg	0.05	3,067
Opex Annual Inflator (%)		1%	
TOTAL OPEX			530,903

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal fish drying to the cost of identified conventional fish drying systems including open air sun drying, solar drying, and wood-fired systems. **Table 169** presents the results of the analysis showing the total annualized cost of each system.

Table 169: Fish Drying Energy Systems Cost Comparison

	FISH DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	10.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	150	300	300	300
Max Annual Capacity per Dryer (Kg)	1,500.0	300,000.0	300,000.0	300,000.0
Volume of Fish Processed per Year (Kg)	300,000	300,000	300,000	300,000
No. of Dryers Required	200.0	1.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$185,000.00	$253,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$12,000.00**	**$4,414.40**	**$9,250.00**	**$10,140.00**
Fuel Requirement (kg/Yr)	-	-	39,135.66	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.18	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$7,044.42**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.16	0.16
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$9,355.15**	**$9,355.15**
Annual Op Costs - Labour ($/Yr)	**$17,382.34**	**$13,905.87**	**$17,382.34**	**$13,905.87**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$6,000.00**	**$8,828.80**	**$18,500.00**	**$25,350.00**
Cost of Lost Revenue ($/Yr)	$294,195.00	-	-	-
Total Annualized Costs ($/Yr)	**$329,577.34**	**$27,149.07**	**$61,531.91**	**$58,751.02**
Total Annual Costs Savings ($/Yr)	**$270,826.31**	**-$31,601.95**	**$2,780.89**	
Total Annual Costs Savings (%)	**82%**	**-116%**	**5%**	

The analysis found that solar drying has the least total annualized costs, followed by geothermal direct-use, wood-fired dryers and open-air sun drying. Switching to geothermal energy will result in costs savings of 5% and 82% compared to wood-fired dryers and open-air sun drying respectively.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the fish drying application, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is attractive with an after-tax equity IRR of 16.41%, payback period of 11 years and an after-tax project IRR of 19.77%. As shown in **Table 170**, the average annual revenue generated by the plant is USD 660,292, while the average total annual expenses are USD 599,776. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 739,149, while net cashflows to be distributed is USD 659,406.

Table 170: Geothermal Fish Drying Analysis Results

FISH DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	65,604
Avg Annual Revenue	$660,292
Avg Annual Expenses	$599,776
Avg EBITDA	$60,516
Total CF to Equity	$739,149
Net CF to Equity	$659,406
Cash on Cash Return	8.27x
After Tax Equity IRR	16.41%
After Tax Project IRR	19.77%
Payback Year	11

- ***Sensitivity Analysis***

  ✓ ***CAPEX Scenarios***

Table 171 shows the impact of increases in CAPEX and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the geothermal fish drying plant will not be viable if CAPEX increases by 20% and above at the production levels analyzed.

Table 171: Geothermal Fish Drying CAPEX Scenarios

		CAPEX						
		$159,486	$212,648	$265,810	$318,972	$372,134	$425,295	$478,457
	16.41%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	1.09%	-5.99%	-14.59%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	8.15%	-0.24%	-5.64%	-11.61%	NEG IRR	NEG IRR	NEG IRR
	200,000	15.76%	4.97%	-1.04%	-5.42%	-10.00%	NEG IRR	NEG IRR
	225,000	24.23%	10.42%	3.13%	-1.57%	-5.26%	-8.96%	-14.24%
	250,000	34.42%	16.17%	7.34%	1.92%	-1.96%	-5.14%	-8.22%
	275,000	45.92%	22.40%	11.82%	5.37%	1.06%	-2.25%	-5.05%
	300,000	58.08%	29.61%	16.41%	8.96%	4.00%	0.41%	-2.47%

  ✓ ***OPEX Scenarios***

Table 172 shows the impact of increases in OPEX and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal fish drying plant will not be viable if OPEX increases by 20% and above at the production levels analyzed. Hence, the project would be unviable if cost of freshwater fish is UGX 15,000 ($4.07) per kg as indicated during the stakeholder survey.

Table 172: Geothermal Fish Drying OPEX Scenarios

		OPEX						
		$318,542	$424,722	$530,903	$637,083	$743,264	$849,444	$955,625
	16.41%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	65.67%	20.55%	-14.59%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	175,000	87.33%	31.64%	-5.64%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	109.08%	44.73%	-1.04%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	225,000	130.82%	58.85%	3.13%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	152.56%	73.34%	7.34%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	275,000	174.29%	87.94%	11.82%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	300,000	196.01%	102.57%	16.41%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 173 shows the impact of increases in the price of dry fish and the quantity of fresh fish processed at 20% and 25,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results also reveal that the geothermal fish drying plant will not be viable if prices decrease by 20% and above at the production levels analyzed. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will not be viable if the quantity of fresh fish processed falls below 275,000kg.

Table 173: Geothermal Fish Drying Price Scenarios

		Price						
		$5.35	$7.13	$8.91	$10.69	$12.48	$14.26	$16.04
	16.41%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	150,000	NEG IRR	NEG IRR	-14.59%	20.84%	66.68%	117.88%	169.09%
	175,000	NEG IRR	NEG IRR	-5.64%	33.23%	91.19%	150.99%	210.70%
	200,000	NEG IRR	NEG IRR	-1.04%	47.87%	115.78%	184.07%	252.28%
	225,000	NEG IRR	NEG IRR	3.13%	63.53%	140.36%	217.14%	293.86%
	250,000	NEG IRR	NEG IRR	7.34%	79.49%	164.92%	250.21%	335.44%
	275,000	NEG IRR	NEG IRR	11.82%	95.53%	189.47%	283.26%	377.01%
	300,000	NEG IRR	NEG IRR	16.41%	111.58%	214.02%	316.32%	418.58%

In conclusion, the geothermal fish drying plant is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that a slight increase in CAPEX/OPEX or decrease in prices will make the plant unviable.

2.6.4 ***Direct Use Geothermal Project****: TEA PROCESSING (Retrofit)*
Applicable Sites: *Buranga, Panyimur*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of retrofitting a tea drying plant, producing 2,000 tons of processed tea per year, to operate on geothermal heat is estimated at USD 118,500 (**Table 174**).

Table 174: Geothermal Tea Drying Plant Retrofit Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	40,000
Pumps	3,500
Well Drilling	30,000
Pipes	45,000
Total CAPEX ($ USD)	**118,500**

- ***Operating Costs***

It is assumed that all the regular operating costs of the existing facility (except fuel costs which will be eliminated by the retrofit and reduced labor costs) will remain the same, while the annual O&M cost of the geothermal direct-use system and retrofits is estimated at 10% of project CAPEX – USD 11,850.

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal tea drying to the cost of identified conventional tea drying systems including diesel-fired and wood-fired dryers. **Table 175** presents the results of the analysis showing the total annualized cost of each system.

Table 175: Geothermal Tea Drying Energy Systems Cost Comparison

	TEA DRYING ENERGY SYSTEMS COST COMPARISON		
	Diesel	Wood	Geothermal
Output per Batch per Dryer (Kg)	1,722.9	1,722.9	1,722.9
No. of Batches per Year per Dryer	600	600	600
Annual Output per Dryer (Kg)	1,033,738.8	1,033,738.8	1,033,738.8
Volume of Processed Tea per Year (Kg)	2,067,478	2,067,478	2,067,478
No. of Dryers Required	2.0	2.0	2.0
Heating Equipment Costs per Dryer ($)	$20,000.00	$30,000.00	$118,500.00
Design Life - Heating Equipment (Yrs)	20	20	25
Annualized Capital Cost ($/Yr)	**$2,000.00**	**$3,000.00**	**$4,740.00**
Fuel Requirement (kWh/Kg)	5.50	5.50	-
Fuel Costs ($/kWh)	$0.08	$0.02	$0.00
Annual Op Costs - Fuel ($/Yr)	**$909,690.12**	**$204,680.28**	**$0.00**
Electricity Requirement (kWh/Kg)	1.00	1.00	1.00
Electricity Cost ($/kWh)	$0.15	$0.15	$0.15
Annual Op Costs - Electricity ($/Yr)	**$310,121.63**	**$310,121.63**	**$310,121.63**
Plant Labor Required per Dryer	30.00	40.00	30.00
Total Plant Labor Required	60.00	80.00	60.00
Labor Costs ($/hr)	$0.77	$0.77	$0.77
No. of Drying Days per Year	300.00	300.00	300.00
Annual Op Costs - Labour ($/Yr)	**$278,117.37**	**$370,823.16**	**$278,117.37**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$4,000.00**	**$6,000.00**	**$11,850.00**
Cost of Lost Revenue ($/Yr)	-	-	-
Other Costs ($/Yr)	-	-	-
Total Annualized Costs ($/Yr)	**$1,503,929.12**	**$894,625.07**	**$604,829.00**
Total Annual Costs Savings ($/Yr)	**$899,100.12**	**$289,796.07**	
Total Annual Costs Savings (%)	**60%**	**32%**	

The analysis found that geothermal direct use has the least total annualized costs, followed by firewood and diesel. Switching to geothermal energy will result in costs savings of 32% and 60% compared to wood and diesel, respectively, mainly due to the avoided fuel expenditure. However, the sensitivity analysis presented below shows that with a major increase in the CAPEX to USD 2.3 million, the geothermal option becomes costlier than wood by 1%.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the tea drying plant retrofit project, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is very attractive with an after-tax equity IRR of 512.32%, payback period of 1 year and an after-tax project IRR of 179.61%. As shown in **Table 176**, the annual cost savings realized by the plant is USD 289,796. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 4.57 million while net cashflows to be distributed is USD 4.54 million.

Table 176: Geothermal Tea Drying Plant Retrofit Analysis Results

TEA PROCESSING RESULTS SUMMARY	
Annual Cost Savings	$289,796.07
Total CF to Equity	$4,572,329
Net CF to Equity	$4,536,779
Cash on Cash Return	127.62x
After Tax Equity IRR	512.32%
After Tax Project IRR	179.61%
Payback Year	1

- ***Sensitivity Analysis***

Table 177 shows the impact of increases in CAPEX at 200% intervals on the equity IRR, payback period, and cost savings. The results reveal that the tea processing plant retrofit will not be viable if CAPEX increases up to USD 1.5 million and above.

Table 177: Geothermal Tea Drying Plant Retrofit Sensitivity Analysis

		Equity IRR	Payback (Yrs)	Cost Savings ($/Yr)	Cost Savings (%)
CAPEX		512.32%	1	$289,796.07	32%
118,500	0%	512.32%	1	$289,796.07	32%
355,500	200%	124.92%	1	$256,616.07	29%
592,500	400%	56.38%	2	$223,436.07	25%
829,500	600%	31.17%	4	$190,256.07	21%
1,066,500	800%	18.35%	7	$157,076.07	18%
1,303,500	1000%	10.81%	12	$123,896.07	14%
1,540,500	1200%	5.33%	16	$90,716.07	10%
1,777,500	1400%	-0.17%	NONE	$57,536.07	6%
2,014,500	1600%	-7.61%	NONE	$24,356.07	3%
2,251,500	1800%	NEG IRR	NONE	-$8,823.93	-1%
2,488,500	2000%	NEG IRR	NONE	-$42,003.93	-5%

In summary, the geothermal tea processing plant retrofit project is estimated to be very viable based on the current assumptions. However, it is clear from the sensitivity analysis that significant increases in CAPEX will result in lower cost savings which would make the retrofit unviable.

2.6.5 *Direct Use Geothermal Project: FRUIT DRYING (Greenfield)* *Applicable Sites: Panyimur*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal fruit drying plant with a 1-ton/batch capacity is estimated at USD 276,810 (**Table 178**).

Table 178: Geothermal Fruit Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	20,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Construction	60,000
Batch Dryer	65,000
Land Acquisition Cost	1,339.65
Fruit peeling machine	3,500
Fruit Slicing Machine	1,500
Blanching machine	3,000
Pre-cooling machine	30,000
Packaging equipment	10,970
Total CAPEX ($ USD)	**276,810**

- ***Operating Costs***

The operating costs for the first year of the fruit drying plant operation are estimated at USD 251,903 (**Table 179**).

Table 179: Geothermal Fruit Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	*Units*	Cost/Unit	1st Year (USD)
Cost of Fresh Fruit (incl. Transport)	US$/Kg	0.68	169,418
Electricity Costs	US$/kwh	0.16	7,796
Equipment O&M	% of CAPEX	10.0%	27,681
Labor (Non-payroll)	US$/hr	0.77	19,885
Payroll	US$/Yr	N/A	18,438
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	1,591
Distribution/Marketing Expenses	% of Rev	0.5%	1,591
Utilities, Property Tax	US$/sqft	2.0	3,582
Packaging	US$/Kg	0.05	1,827
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**251,903**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal fruit drying to the cost of identified conventional fruit drying systems including open-air sun drying, solar drying, and wood-fired systems. **Table 180** presents the results of the analysis showing the total annualized cost of each system.

Table 180: Fruit Drying Energy Systems Cost Comparison

	FRUIT DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Solar Drying	Wood	Geothermal
Capacity per Batch per Dryer (Kg)	10.0	1,000.0	1,000.0	1,000.0
No. of Batches per Year per Dryer	117	234	468	468
Max Annual Capacity per Dryer (Kg)	1,170.0	234,000.0	468,000.0	468,000.0
Volume of Fruit Processed per Year (Kg)	250,000	250,000	250,000	250,000
No. of Dryers Required	214.0	2.0	1.0	1.0
Heating Equipment Costs per Dryer ($)	$300.00	$88,288.00	$158,000.00	$226,500.00
Design Life - Heating Equipment (Yrs)	5	20	20	25
Annualized Capital Cost ($/Yr)	**$12,840.00**	**$8,828.80**	**$7,900.00**	**$9,060.00**
Fuel Requirement (kg/Yr)	-	-	35,063.25	-
Fuel Costs ($/kg)	$0.00	$0.00	$0.18	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$0.00**	**$6,311.38**	**$0.00**
Electricity Requirement (kWh/Kg)	-	-	0.2	0.2
Electricity Cost ($/kWh)	$0.00	$0.00	0.16	0.16
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$0.00**	**$7,795.96**	**$7,795.96**
Annual Op Costs - Labour ($/Yr)	**$24,856.74**	**$19,885.39**	**$24,856.74**	**$19,885.39**
Annual Maintenance Cost (% of CAPEX)	10%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$6,420.00**	**$17,657.60**	**$15,800.00**	**$22,650.00**
Cost of Lost Revenue ($/Yr)	$159,167.94	-	-	-
Total Annualized Costs ($/Yr)	**$203,284.68**	**$46,371.79**	**$62,664.08**	**$59,391.35**
Total Annual Costs Savings ($/Yr)	**$143,893.32**	**-$13,019.56**	**$3,272.73**	
Total Annual Costs Savings (%)	**71%**	**-28%**	**5%**	

The analysis found that solar drying has the least total annualized costs, followed by geothermal direct-use, wood-fired dryers and open-air sun drying. Switching to geothermal energy will result in costs savings of 5% and 71% compared to wood-fired dryers and open-air sun drying, respectively.

Financial Analysis Results

- ***Indicative Investor Returns***

The analysis of the fruit drying application, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is attractive with an after-tax equity IRR of 20.52%, payback period of 8 years and an after-tax project IRR of 21.88%. As shown in **Table 181**, the average annual revenue generated by the plant is USD 357,214, while the average total annual expenses are USD 284,581. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 937,962, while net cashflows to be distributed is USD 854,919. It is worth noting that the returns for this application are higher compared to the fish drying application mainly due to the lower cost of fresh fruits needed as input for the plant.

Table 181: Geothermal Fruit Drying Analysis Results Summary

FRUIT DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	39,089
Avg Annual Revenue	$357,214.26
Avg Annual Expenses	$284,581.31
Avg EBITDA	$72,632.95
Total CF to Equity	$937,962
Net CF to Equity	$854,919
Cash on Cash Return	10.29x
After Tax Equity IRR	20.52%
After Tax Project IRR	21.88%
Payback Year	8

- ***Sensitivity Analysis***

✓ ***CAPEX Scenarios***

Table 182 shows the impact of increases in CAPEX and the quantity of fresh fruits processed at 20% and 50,000kg intervals respectively on the equity IRR. The results show that the geothermal fruit drying plant will not be viable at the base production level of 250,000kg if CAPEX increases by 40% and above.

Table 182: Geothermal Fruit Drying CAPEX Scenarios

		CAPEX						
		$166,086	$221,448	$276,810	$332,172	$387,534	$442,895	$498,257
	20.52%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	150,000	5.99%	-1.66%	-6.91%	-13.90%	NEG IRR	NEG IRR	NEG IRR
	200,000	31.55%	14.89%	6.50%	1.37%	-2.37%	-5.48%	-8.55%
	250,000	67.74%	36.09%	20.52%	12.26%	6.72%	2.84%	-0.16%
	300,000	105.99%	63.44%	38.91%	24.74%	16.53%	10.97%	6.84%
	350,000	144.29%	92.07%	60.88%	40.83%	28.00%	19.87%	14.45%
	400,000	182.55%	120.80%	83.73%	59.17%	42.22%	30.56%	22.67%

✓ ***OPEX Scenarios***

Table 183 shows the impact of increases in OPEX and the quantity of fresh fruit processed at 20% and 50,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal fruit drying plant will not be viable at the base production level of 250,000kg if OPEX increases by 20% and above.

Table 183: Geothermal Fruit Drying OPEX Scenarios

		OPEX						
		$151,142	$201,522	$251,903	$302,283	$352,664	$403,044	$453,425
	20.52%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	8.02%	-5.82%	NEG IRR	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	150,000	31.75%	10.88%	-6.91%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	200,000	64.86%	30.74%	6.50%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	250,000	100.04%	57.64%	20.52%	-5.07%	NEG IRR	NEG IRR	NEG IRR
	300,000	135.32%	86.57%	38.91%	4.66%	NEG IRR	NEG IRR	NEG IRR
	350,000	170.57%	115.70%	60.88%	14.65%	NEG IRR	NEG IRR	NEG IRR
	400,000	205.82%	144.82%	83.73%	25.99%	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 184 shows the impact of increases in the price of dried fruits and the quantity of fresh fruits processed at 20% and 50,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results also reveal that the geothermal fruit drying plant will not be viable if prices decrease by 20% and above at the production levels analyzed except for the 20% price decrease at 400,000kg scenario. In addition, all the tables show that under the current base assumptions for CAPEX, OPEX and pricing, the plant will not be viable if the quantity of fresh fruit processed falls below 250,000kg.

Table 184: Geothermal Fruit Drying Price Scenarios

		Price						
		$4.85	$6.47	$8.09	$9.71	$11.33	$12.95	$14.56
	20.52%	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	100,000	NEG IRR	NEG IRR	NEG IRR	-8.18%	4.77%	17.39%	33.13%
	150,000	NEG IRR	NEG IRR	-6.91%	11.84%	34.54%	64.84%	96.69%
	200,000	NEG IRR	NEG IRR	6.50%	35.97%	77.08%	119.65%	162.22%
	250,000	NEG IRR	NEG IRR	20.52%	68.14%	121.32%	174.53%	227.68%
	300,000	NEG IRR	-3.91%	38.91%	101.69%	165.56%	229.36%	293.12%
	350,000	NEG IRR	3.14%	60.88%	135.31%	209.77%	284.17%	358.54%
	400,000	NEG IRR	10.17%	83.73%	168.91%	253.96%	338.97%	423.96%

In conclusion, the geothermal fruit drying plant is estimated to be viable based on the current assumptions. However, it is clear from the sensitivity analysis that a slight increase in OPEX or decrease in prices will make the plant unviable. In addition, the projected investor returns are quite attractive but could be made more attractive by maximizing the capacity of the plant to process 468,000kg annually thereby realizing economies of scale. The project would also generate even more attractive returns if it were supported by a grant and/or concessional debt with much lower interest rate than the 23.1% assumed.

2.6.6 ***Direct Use Geothermal Project:*** *RICE DRYING (Greenfield)*
Applicable Sites: *Panyimur*

Cost Estimate

The capital and operating cost estimates presented below are based on publicly available information, and, where available, information obtained from local stakeholder interviews. It is important to note that a detailed feasibility study will be required to determine the actual applicable costs.

- ***Capital Costs***

The total capital cost of a newly constructed geothermal rice drying plant with a 5-ton/batch capacity is estimated at USD 528,810 (**Table 185**).

Table 185: Geothermal Rice Drying Plant Capital Cost Estimates

CAPITAL EXPENSES	Cost (USD)
Heat Exchanger	60,000
Pumps	3,500
Well Drilling	30,000
Fans	3,000
Pipes	45,000
Construction	180,000
Batch Dryers	195,000
Packaging equipment	10,970
Land Acquisition Cost	1,339.65
Total CAPEX ($ USD)	**528,810**

- ***Operating Costs***

The operating costs for the first year of the rice drying plant operation are estimated at USD 1,903,250 (**Table 186**).

Table 186: Geothermal Rice Drying Plant Annual Operating Cost Estimates

OPERATING EXPENSES	*Units*	Cost/Unit	1st Year (USD)
Cost of Fresh Rice (incl. Transport)	US$/Kg	0.95	1,707,738
Electricity Costs	US$/kwh	0.16	56,131
Equipment O&M	% of CAPEX	10.0%	52,881
Labor (Non-payroll)	US$/hr	0.77	25,031
Payroll	US$/Yr	N/A	18,438
Insurances	US$/Yr	92	92
Equipment Leases	US$/Yr	-	-
Office and Admin Expenses	% of Rev	0.5%	10,496
Distribution/Marketing Expenses	% of Rev	0.5%	10,496
Utilities, Property Tax	US$/sqft	2.0	6,458
Packaging	US$/Kg	0.01	15,488
Opex Annual Inflator (%)		1%	
TOTAL OPEX			**1,903,250**

Cost Comparison

A cost comparison analysis was conducted to compare the cost of geothermal rice drying to the cost of identified conventional rice drying systems including open air sun drying, rice husk and diesel-fired dryers. **Table 187** presents the results of the analysis showing the total annualized cost of each system.

Table 187: Rice Drying Energy Systems Cost Comparison

	RICE DRYING ENERGY SYSTEMS COST COMPARISON			
	Open Air Sun Drying	Rice Husk	Diesel	Geothermal
Capacity per Batch per Dryer (Kg)	-	5,000.0	5,000.0	5,000.0
No. of Batches per Year per Dryer	0	120	120	120
Max Annual Capacity per Dryer (Kg)	-	600,000.0	600,000.0	600,000.0
Volume of Rice Processed per Year (Kg)	1,800,000	1,800,000	1,800,000	1,800,000
No. of Dryers Required	-	3.0	3.0	3.0
Heating Equipment Costs per Dryer ($)	$450.00	$30,000.00	$20,000.00	$138,500.00
Design Life - Heating Equipment (Yrs)	1	20	20	25
Annualized Capital Cost ($/Yr)	**$450.00**	**$4,500.00**	**$3,000.00**	**$5,540.00**
Fuel Requirement (kg or Ltr/Yr)	-	69,568.99	15,875.91	-
Fuel Costs ($/kg or Ltr)	$0.00	$0.04	$1.01	$0.00
Annual Op Costs - Fuel ($/Yr)	**$0.00**	**$2,451.54**	**$16,050.54**	**$0.00**
Electricity Requirement (kWh/Kg)	-	0.2	0.2	0.2
Electricity Cost ($/kWh)	$0.00	0.16	0.16	0.16
Annual Op Costs - Electricity ($/Yr)	**$0.00**	**$56,130.92**	**$56,130.92**	**$56,130.92**
Annual Op Costs - Labour ($/Yr)	**$37,545.84**	**$25,030.56**	**$25,030.56**	**$25,030.56**
Annual Maintenance Cost (% of CAPEX)	0%	10%	10%	10%
Annual Maintenance Cost ($/Yr)	**$0.00**	**$9,000.00**	**$6,000.00**	**$13,850.00**
Cost of Lost Revenue ($/Yr)	**$526,604.65**	-	-	-
Total Annualized Costs ($/Yr)	**$564,600.50**	**$97,113.02**	**$106,212.02**	**$100,551.48**
Total Annual Costs Savings ($/Yr)	**$464,049.02**	**-$3,438.46**	**$5,660.54**	
Total Annual Costs Savings (%)	**82%**	**-4%**	**5%**	

The analysis showed that rice husk-fired dryers have the least total annualized costs due to the assumed low cost of rice husks. However, switching to geothermal energy will result in costs savings of 82% and 5% compared to open air sun drying and diesel-fired dryers respectively. However, it is important to note that the results could be very different with a major increase in the CAPEX for the geothermal option.

Financial Analysis Results

- ***Indicative Investor Returns***

The financial analysis of the rice drying application, based on the assumptions detailed in **Annex 1**, found that the investment opportunity is very attractive with an after-tax equity IRR of 45.42%, payback period of only 3 years and an after-tax project IRR of 31.41%. As shown in **Table 188**, the average annual revenue generated by the plant is USD 2.36 million, while the average total annual expenses are USD 2.15 million. The total cumulative cashflows to be distributed to investors over the life of the plant is USD 2.98 million, while net cashflows to be distributed is USD 2.82 million. These results underscore the value of leveraging on economies of scale.

Table 188: Geothermal Rice Drying Analysis Results

RICE DRYING RESULTS SUMMARY	
Avg Annual Sales (Kg)	1,539,544
Avg Annual Revenue	$2,356,697.63
Avg Annual Expenses	$2,150,154.68
Avg EBITDA	$206,542.95
Total CF to Equity	$2,978,128
Net CF to Equity	$2,819,485
Cash on Cash Return	17.77x
After Tax Equity IRR	45.42%
After Tax Project IRR	31.41%
Payback Year	3

- ***Sensitivity Analysis***

✓ ***CAPEX Scenarios***

Table 189 shows the impact of increases in CAPEX and the quantity of freshly harvested rice processed at 20% and 250,000kg intervals respectively on the equity IRR. The results show that the geothermal rice drying plant will remain viable at the base production level of 1,800,000kg even with increase in CAPEX up to 60%.

Table 189: Geothermal Rice Drying CAPEX Scenarios

		CAPEX						
		$317,286	$423,048	$528,810	$634,572	$740,334	$846,095	$951,857
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	500,000	36.95%	17.29%	8.05%	2.36%	-1.65%	-4.91%	-8.03%
	750,000	66.44%	34.85%	19.43%	11.24%	5.72%	1.83%	-1.20%
	1,000,000	85.92%	48.46%	28.09%	17.25%	10.65%	5.92%	2.44%
	1,250,000	99.48%	58.38%	34.97%	21.81%	14.24%	8.87%	4.95%
	1,500,000	109.45%	65.79%	40.37%	25.49%	16.84%	11.13%	6.83%
	1,750,000	117.08%	71.49%	44.67%	28.49%	18.95%	12.90%	8.31%
	2,000,000	123.11%	76.00%	48.12%	30.98%	20.70%	14.30%	9.51%

✓ ***OPEX Scenarios***

Table 190 shows the impact of increases in OPEX and the quantity of fresh rice processed at 20% and 250,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in OPEX than CAPEX. The results also reveal that the geothermal rice drying plant will not be viable if OPEX increases by 20% and above at the production levels analyzed.

Table 190: Geothermal Rice Drying OPEX Scenarios

		OPEX						
		$1,135,652	$1,514,203	$1,892,754	$2,271,305	$2,649,855	$3,028,406	$3,406,957
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	500,000	235.27%	115.70%	8.05%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	750,000	289.45%	151.95%	19.43%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	1,000,000	324.11%	175.13%	28.09%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	1,250,000	348.19%	191.23%	34.97%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	1,500,000	365.89%	203.06%	40.37%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	1,750,000	379.45%	212.13%	44.67%	NEG IRR	NEG IRR	NEG IRR	NEG IRR
	2,000,000	390.18%	219.30%	48.12%	NEG IRR	NEG IRR	NEG IRR	NEG IRR

✓ ***Price Scenarios***

Table 191 shows the impact of increases in the price of dry rice and the quantity of fresh rice processed at 20% and 250,000 intervals respectively on the equity IRR. The results show that the equity IRR is more sensitive to changes in pricing than CAPEX and OPEX. The results also reveal that the geothermal rice drying plant will not be viable if prices decrease by 20% and above at the production levels analyzed. In addition, all the tables show that under the current base case assumptions for CAPEX, OPEX and pricing, the plant will be viable unless the quantity of fresh rice processed falls below 750,000kg.

Table 191: Geothermal Rice Dying Price Scenarios

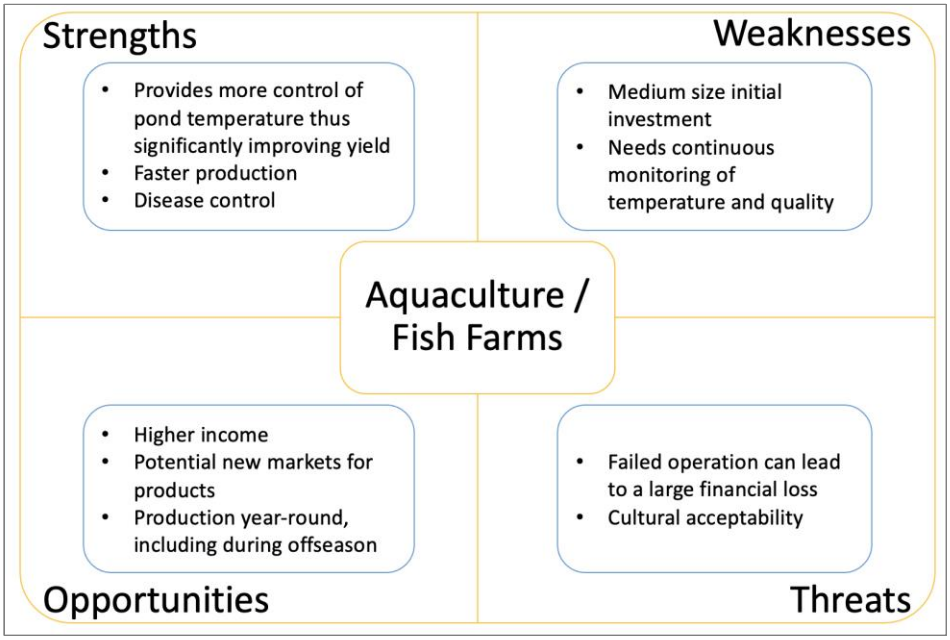
		Price						
		$0.81	$1.08	$1.36	$1.63	$1.90	$2.17	$2.44
	NEG IRR	-40%	-20%	0%	20%	40%	60%	80%
Quantity (Kg)	500,000	NEG IRR	NEG IRR	8.05%	121.85%	247.60%	373.18%	498.73%
	750,000	NEG IRR	NEG IRR	19.43%	161.54%	308.63%	455.60%	602.54%
	1,000,000	NEG IRR	NEG IRR	28.09%	186.91%	347.67%	508.33%	668.96%
	1,250,000	NEG IRR	NEG IRR	34.97%	204.53%	374.79%	544.96%	715.11%
	1,500,000	NEG IRR	NEG IRR	40.37%	217.48%	394.73%	571.89%	749.03%
	1,750,000	NEG IRR	NEG IRR	44.67%	227.40%	410.01%	592.53%	775.03%
	2,000,000	NEG IRR	NEG IRR	48.12%	235.25%	422.09%	608.84%	795.58%

In conclusion, the geothermal rice drying plant is estimated to be very viable with attractive projected returns, based on the current assumptions. However, it is clear from the sensitivity analysis that a slight increase in OPEX or decrease in prices will make the plant unviable

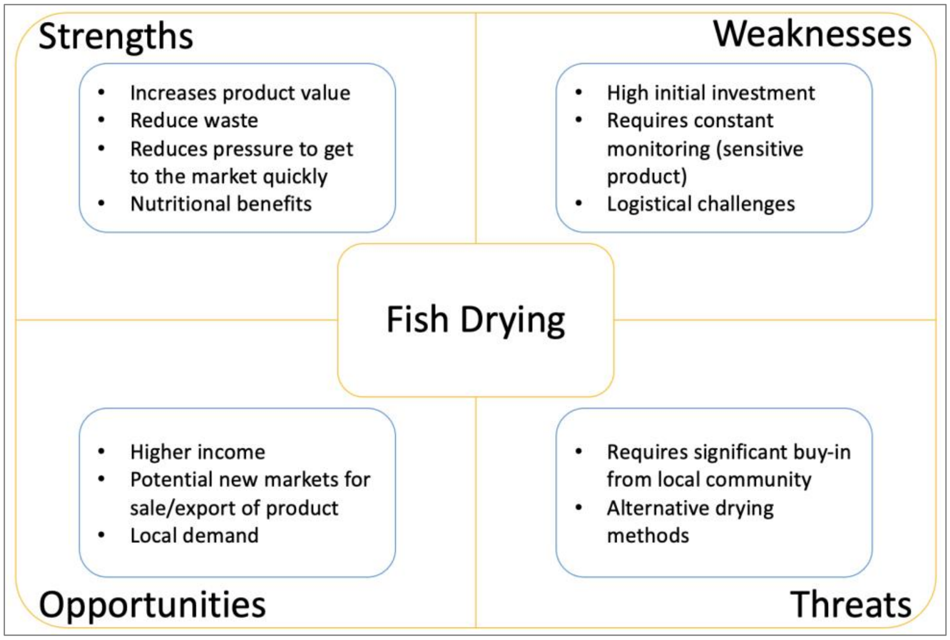
III. SWOT ANALYSIS OF DIRECT USE TECHNOLOGIES

This section summarizes the key market trends, entry barriers, competition, risks, and opportunities for each direct use technology through a Strength-Weaknesses-Opportunities-Threats (SWOT) analysis.

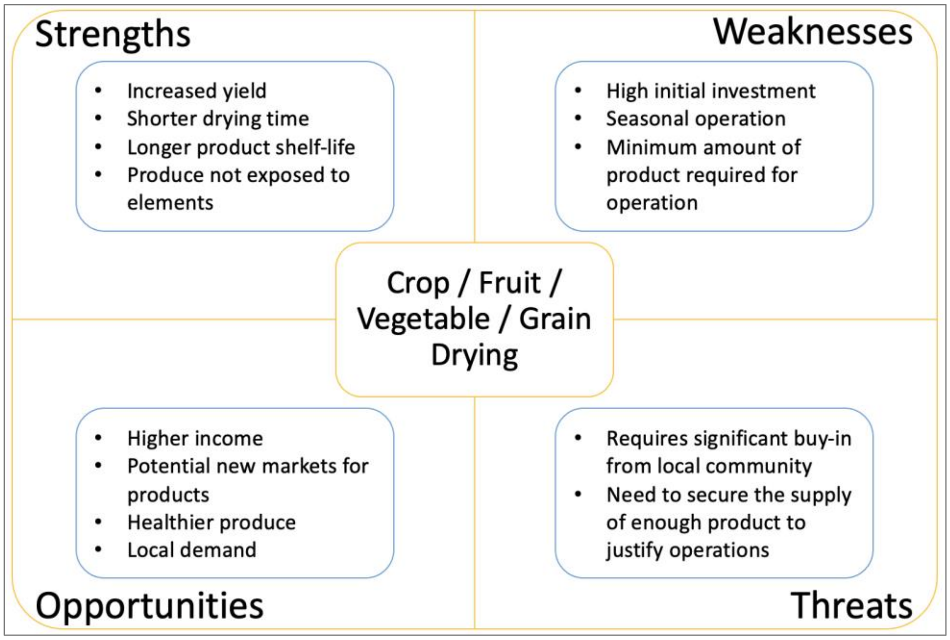
1. AQUACULTURE / FISH FARMING



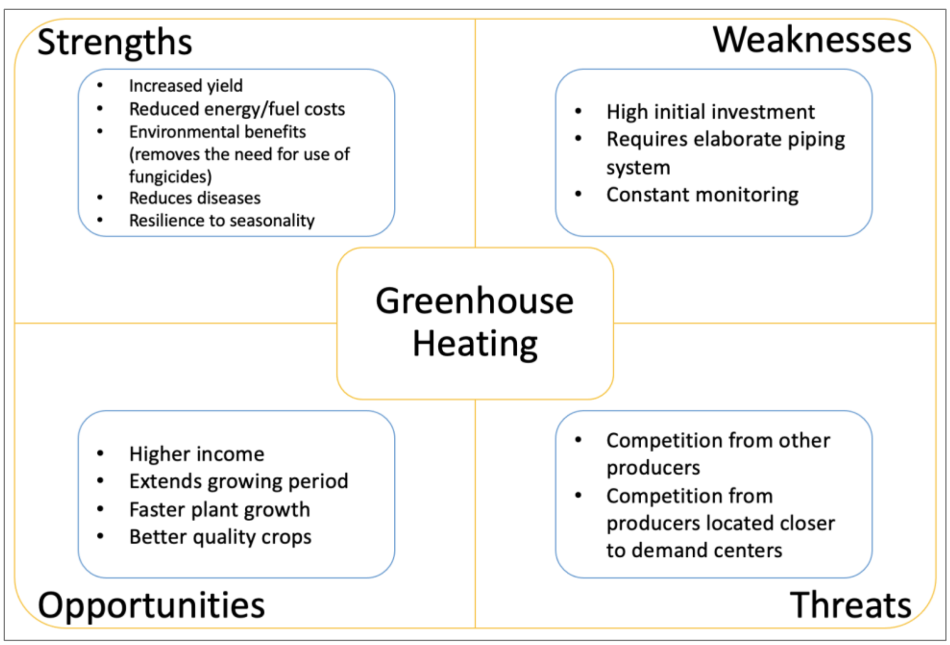
2. FISH DRYING



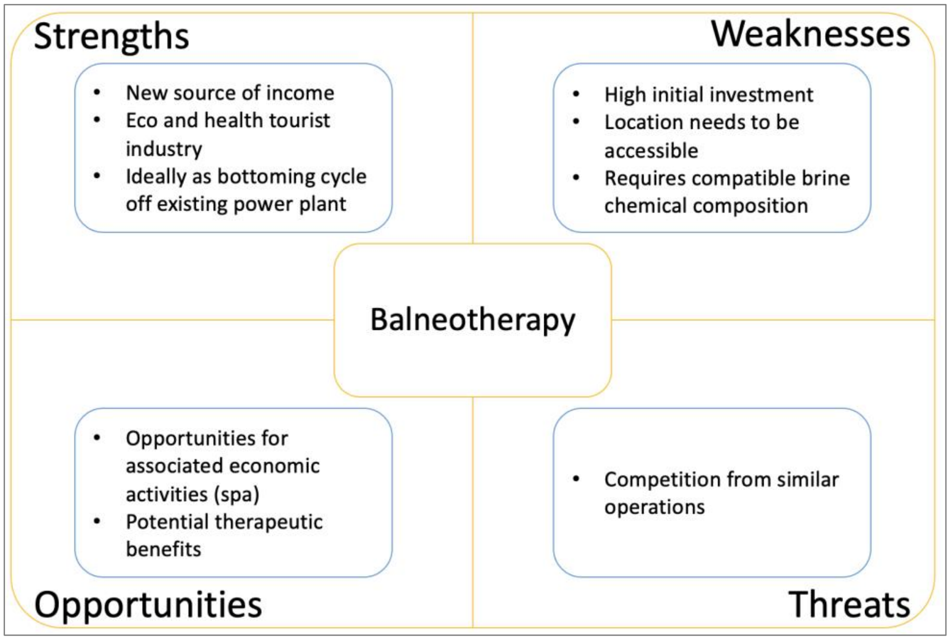
3. CROP / FRUIT / VEGETABLE / GRAIN DRYING



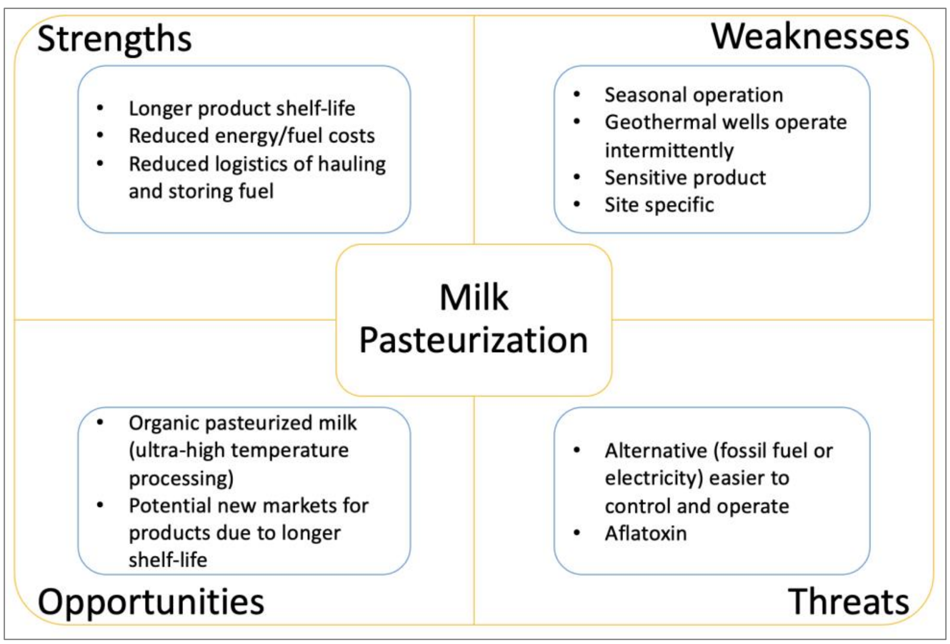
4. GREENHOUSE HEATING



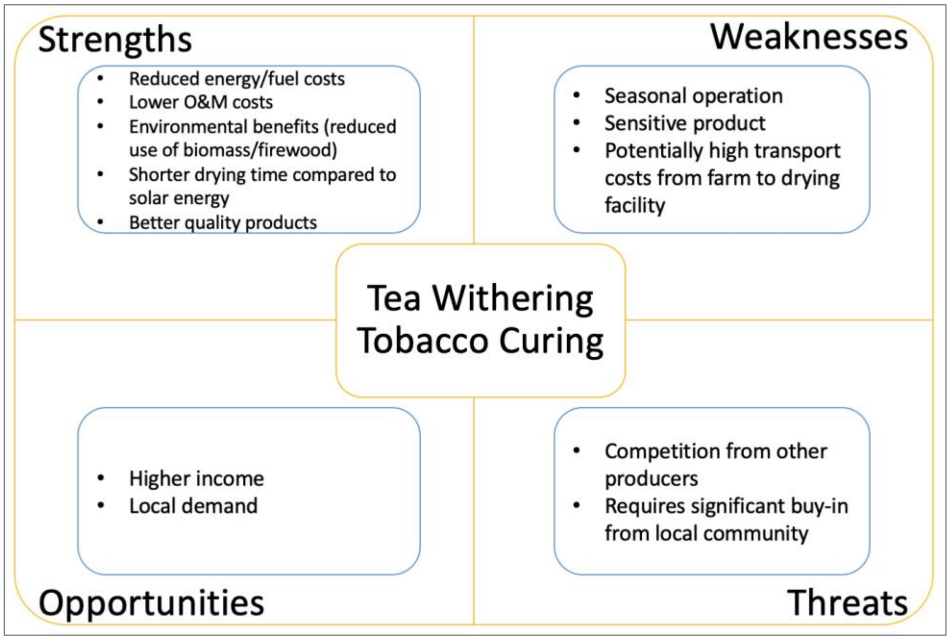
5. BALNEOTHERAPY



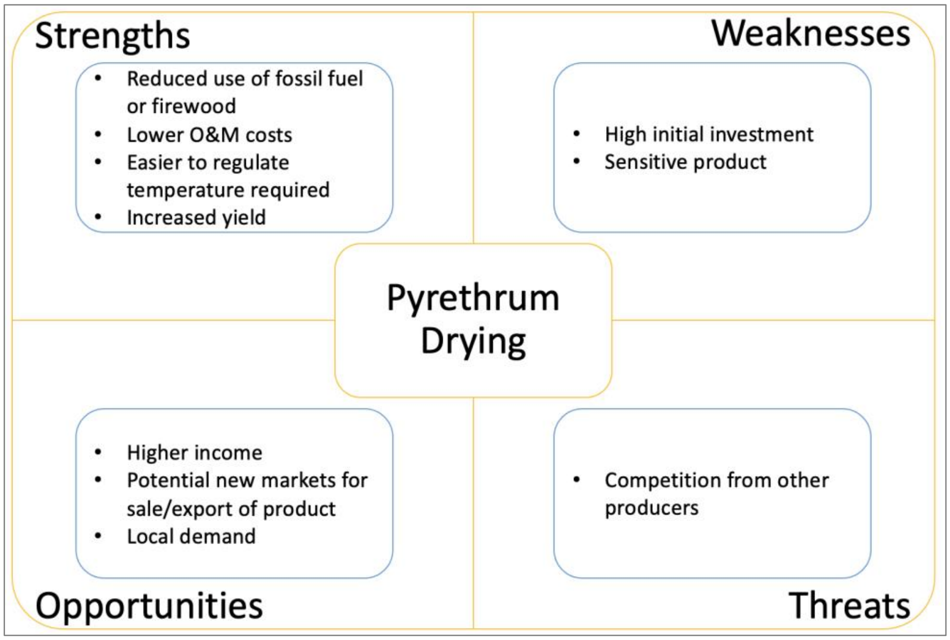
6. MILK PASTEURIZATION



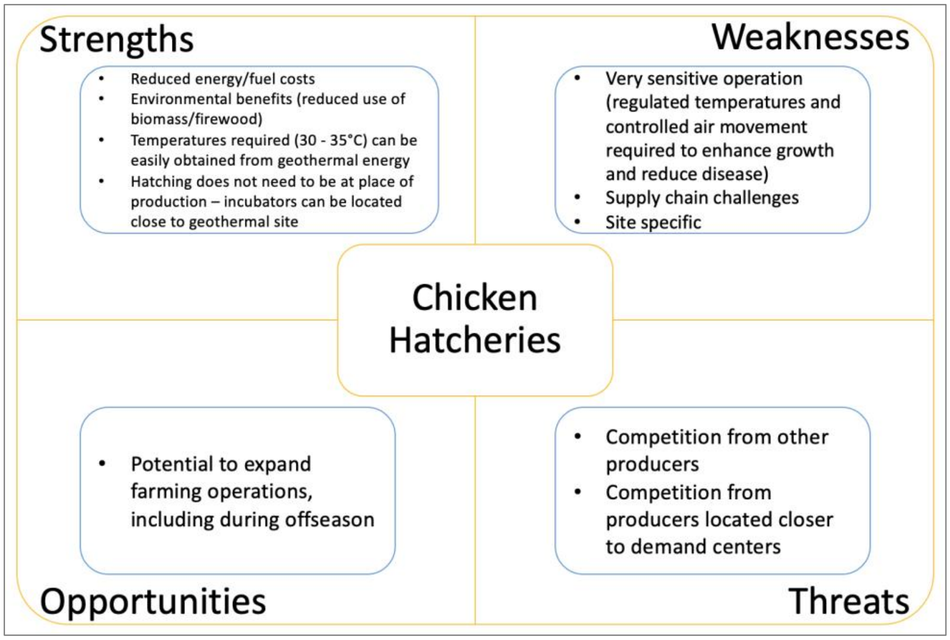
7. TEA PROCESSING / TOBACCO CURING



8. PYRETHRUM DRYING



9. CHICKEN HATCHERIES



ANNEX 1: METHODOLOGY AND KEY ASSUMPTIONS

A summary of the approach, methods and assumptions used to analyze the categorized direct use projects in each country is presented below; the results of this analysis are presented in **Section II** of this report.

In the tables below, a plain white cell refers to a calculated value, while a cell with blue colored text refers to a hard-coded input.

KEY
Calculation
Active Input
Inactive Input

1) Technical Assumptions

Tables A1-A12 present the assumptions related to the processing capacity of the analyzed geothermal direct use projects. These technical assumptions remain the same throughout the entire life of the projects.

Table A-1: Geothermal Fish Drying Technical Assumptions

TECHNICAL INPUTS	*Value*	*Units*
Quantity of Fresh Fish Processed	300,000	Kg/Yr
Avg Moisture Content of Fresh Fish	80.0%	%
Desired Moisture Content of Dried fish	10.0%	%
Amt of Moisture to be Removed	233,333.33	Kg/Yr
Quantity of Dried Fish Produced	66,666.67	Kg/Yr
% Dried Fish Loss due to Inspection	1%	%
Quantity of Marketable Dried Fish	66,000.00	Kg/Yr
Quantity of Electricity required	0.2	Kwh/kg
Typical Drying Area Reqd	6.01	Kg/sqm
Required Drying Time	8.8	Hrs/Batch
Washing, Sorting, Packaging etc. Time	1.2	Hrs/Batch
Station Annual Operating Hours	3,000	Hrs/Yr
No. of Batches per Year	300.0	Batches/Yr
Quantity of Fresh Fish Processed per Batch	1000	Kg/Batch
Total Required Drying Area	166.40	Sqm
Assumed Total Station Land Size	500	Sqm
Annual Plant Output Degradation	0.05%	%

Table A-2: Geothermal Fruit Drying Technical Assumptions

TECHNICAL INPUTS	Value	Units
Quantity of Fresh Fruit Processed	250,000	Kg/Yr
Avg Moisture Content of Fresh Fruit	85.7%	%
Desired Moisture Content of Dried Fruit	10.0%	%
Amt of Moisture to be Removed	210,277.78	Kg/Yr
Quantity of Dried Fruit Produced	39,722.22	Kg/Yr
% Dried Fruit Loss due to Inspection	1%	%
Quantity of Marketable Dried Fruit	39,325.00	Kg/Yr
Quantity of Electricity required	0.2	Kwh/kg
Required Drying Time	8.8	Hrs/Batch
Washing, Peeling, Slicing, Packaging etc. Time	2.2	Hrs/Batch
Station Annual Operating Hours	5,148	Hrs/Yr
Quantity of Fresh Fruit Processed per Batch	1,000.0	Kg/Batch
No. of Drying Days per Year	234.0	Days/Yr
No. of Batches per Day per Dryer	2.0	Batches/Day
No. of Batches per Year per Dryer	468.0	Batches/Yr
Annual Fruit Drying Capacity per Dryer	468,000.00	Kg/Yr
No. of Dryers Required	1.00	#
Land Space Required per Dryer	166.4	Sqm
Assumed Total Station Land Size	500	Sqm
Annual Plant Output Degradation	0.05%	%

Table A-3: Geothermal Vegetable Drying Technical Assumptions

TECHNICAL INPUTS	Value	Units
Quantity of Fresh Veg Processed	550,000	Kg/Yr
Avg Moisture Content of Fresh Veg	87.0%	%
Desired Moisture Content of Dried Veg	10.0%	%
Amt of Moisture to be Removed	470,555.56	Kg/Yr
Quantity of Dried Veg Produced	79,444.44	Kg/Yr
% Dried Veg Loss due to Inspection	1%	%
Quantity of Marketable Dried Veg	78,650.00	Kg/Yr
Quantity of Electricity required	0.2	Kwh/kg
Typical Drying Area Reqd	2.0	Kg/sqm
Required Drying Time	5.0	Hrs/Batch
Washing, Blanching, Packaging etc. Time	2.0	Hrs/Batch
Station Annual Operating Hours	4,200	Hrs/Yr
Quantity of Fresh Veg Processed per Batch	1,000.0	Kg/Batch
No. of Drying Days per Year	300.0	Days/Yr
No. of Batches per Day per Dryer	2.0	Batches/Day
No. of Batches per Year per Dryer	600.0	Batches/Yr
Annual Veg Drying Capacity per Dryer	600,000.00	Kg/Yr
No. of Dryers Required	1.00	#
Land Space Required per Dryer	500.0	Sqm
Assumed Total Station Land Size	750	Sqm
Annual Plant Output Degradation	0.05%	%

Table A-4: Geothermal Pyrethrum Drying Technical Assumptions

TECHNICAL INPUTS	Value	Units
Quantity of Fresh Pyrethrum Processed	102,000	Kg/Yr
Avg Moisture Content of Fresh Pyrethrum	82.0%	%
Desired Moisture Content of Dried Pyrethrum	10.0%	%
Amt of Moisture to be Removed	81,600.00	Kg/Yr
Quantity of Dried Pyrethrum Produced	20,400.00	Kg/Yr
% Dried Pyrethrum Loss due to Inspection	1%	%
Quantity of Marketable Dried Pyrethrum	20,196.00	Kg/Yr
Quantity of Electricity required	0.2	Kwh/kg
Typical Drying Area Reqd	2.0	Kg/sqm
Required Drying Time	21.0	Hrs/Batch
Washing, Grinding, Packaging etc. Time	1.0	Hrs/Batch
Station Annual Operating Hours	5,720	Hrs/Yr
Quantity of Pyrethrum Processed per Batch	1,000.0	Kg/Batch
No. of Drying Days per Year	260.0	Days/Yr
No. of Batches per Day per Dryer	1.0	Batches/Day
No. of Batches per Year per Dryer	260.0	Batches/Yr
Annual Veg Drying Capacity per Dryer	260,000.00	Kg/Yr
No. of Dryers Required	1.00	#
Land Space Required per Dryer	500.0	Sqm
Assumed Total Station Land Size	750	Sqm
Annual Plant Output Degradation	0.05%	%

Table A-5: Geothermal Rice Drying Technical Assumptions

TECHNICAL INPUTS	Value	Units
Quantity of Fresh Rice Processed	1,800,000	Kg/Yr
Avg Moisture Content of Fresh Rice	26.0%	%
Desired Moisture Content of Dried Rice	14.0%	%
Amt of Moisture to be Removed	251,162.79	Kg/Yr
Quantity of Dried Rice Produced	1,548,837.21	Kg/Yr
Quantity of Electricity required	0.2	Kwh/kg
Required Drying Time	8.0	Hrs/Batch
Grain Cleaning, Loading, Storage etc. Time	1.0	Hrs/Batch
Station Annual Operating Hours	1,080	Hrs/Yr
Quantity of Fresh Rice Processed per Batch	5,000.0	Kg/Batch
No. of Drying Days per Year	60.0	Days/Yr
No. of Batches per Day per Dryer	2.0	Batches/Day
No. of Batches per Year per Dryer	120.0	Batches/Yr
Annual Rice Drying Capacity per Dryer	600,000.00	Kg/Yr
No. of Dryers Required	3	#
Land Space Required per Dryer	100	Sqm
Assumed Total Station Land Size	500	Sqm
Annual Plant Output Degradation	0.05%	%

Table A-6: Geothermal Spa Technical Assumptions

TECHNICAL INPUTS	*Value*	*Units*
Total # of Visitors per Year	14,000	#
Size of Bathing Lagoon	2,800.0	m2
Average Lagoon Depth	1.0	m
Lagoon Volume	2,800.0	m3
Required Pump Power Demand	15.0	kW
Bathing Time per User	1.0	Hrs/Bath
Spa Annual Operating Hours	3,948	Hrs/Yr
Max # of Bathers per Use	1,000.0	#
No. of Operating Days per Year	329.0	Days/Yr
Daily Operating Hours	12.0	Hrs/Yr
Max Annual Visitor Capacity	3,948,000.00	#
Assumed Total Spa Land Size	4,000	m2

Table A-7: Geothermal Tea Processing Technical Assumptions

TECHNICAL INPUTS	*Value*	*Units*
Quantity of Fresh Tea Processed	12,000,000	Kg/Yr
Avg Moisture Content of Fresh Tea	83.0%	%
Desired Moisture Content of Dried Tea	2.0%	%
Amt of Moisture to be Removed	9,918,367.35	Kg/Yr
Quantity of Dried Tea Produced	2,081,632.65	Kg/Yr
% Dried Tea Solid Waste	0.68%	%
Quantity of Marketable Dried Tea	2,067,477.55	Kg/Yr
Quantity of Electricity required	1.0	Kwh/kg
Required Withering & Drying Time	10.0	Hrs/Batch
Station Annual Operating Hours	6,000	Hrs/Yr
Quantity of Fresh Tea Processed per Batch	10,000.0	Kg/Batch
Batches/day/dryer	2	Batch/Day
Plant Op Time (Days/Week)	6	Days/Week
Plant Op Time (Weeks/Yr)	50	Weeks/Yr
No. of Drying Days per Year	300.0	Days/Yr
No. of Batches per Day per Dryer	2.0	Batches/Day
No. of Batches per Year per Dryer	600.0	Batches/Yr
Annual Tea Drying Capacity per Dryer	6,000,000.00	Kg/Yr
No. of Dryers Required	2.00	#

Table A-8: Geothermal Tobacco Curing Technical Assumptions

TECHNICAL INPUTS	Value	Units
Quantity of Fresh Tobacco Processed	2,890,000	Kg/Yr
Avg Moisture Content of Fresh Tobacco	78.0%	%
Desired Moisture Content of Dried Tobacco	16.0%	%
Amt of Moisture to be Removed	2,133,095.24	Kg/Yr
Quantity of Dried Tobacco Produced	756,904.76	Kg/Yr
% Dried Tobacco Loss due to Inspection	1%	%
Quantity of Marketable Dried Tobacco	749,335.71	Kg/Yr
Quantity of Electricity required	0.88	Kwh/kg
Required Curing Time	140.0	Hrs/Batch
Station Annual Operating Hours	5,096	Hrs/Yr
Quantity of Tob Processed per Batch per barn	4,630.0	Kg/Batch
Plant Op Time	7	Days/Week
Plant Op Time	30.3	Weeks/Yr
Batches/Day/Barn	0.17	Batch/Day
No. of Curing Days per Year	212.3	Days/Yr
No. of Batches per Day per Barn	0.2	Batches/Day
No. of Batches per Year per Barn	36.4	Batches/Yr
Annual Tob Drying Capacity per Barn	168,532.00	Kg/Yr
No. of Barns Required	18.00	#

Table A-9: Geothermal Greenhouse Heating Technical Assumptions (Tanzania)

TECHNICAL INPUTS	Value	Units
Greenhouse floor size	240.0	sqm
Greenhouse floor size	2,583.34	sqft
Thermal Energy Requirement	98.41	BTU/hr/sqft
Hourly Thermal Energy Requirement	254,226.10	BTU/hr
Hourly Thermal Energy Requirement	268,223.78	KJ/hr
Heating Time (Hours/Day)	12	Hrs/Day
Heating Time (Days/Week)	7	Days/Week
Heating Time (Weeks/Yr)	51	Weeks/Yr
Annual Thermal Energy Requirement	1,149,070.69	MJ/Yr

Table A-10: Geothermal Greenhouse Heating Technical Assumptions (Ethiopia and Kenya)

TECHNICAL INPUTS	Value	Units
Greenhouse floor size	5,000.0	sqm
Greenhouse floor size	53,819.50	sqft
Thermal Energy Requirement	98.41	BTU/hr/sqft
Hourly Thermal Energy Requirement	5,296,377.00	BTU/hr
Hourly Thermal Energy Requirement	5,587,995.51	KJ/hr
Heating Time (Hours/Day)	12	Hrs/Day
Heating Time (Days/Week)	7	Days/Week
Heating Time (Weeks/Yr)	51	Weeks/Yr
Annual Thermal Energy Requirement	23,938,972.77	MJ/Yr

Table A-11: Geothermal Chicken Hatchery Technical Assumptions

TECHNICAL INPUTS	Value	Units
Required Incubation Time	21.0	Days/Batch
Station Annual Operating Hours	8,568	Hrs/Yr
Incubator Capacity per Batch	100,000	#/Batch
No. of Incubation Days per Year	357.0	Days/Yr
No. of Batches per Day per Incubator	0.048	Batches/Day
Plant Op Time	7	Days/Week
Plant Op Time	51	Weeks/Yr
No. of Batches per Year per Incubator	17.0	Batches/Yr
Annual Production Capacity per Incubator	1,700,000.00	Eggs/Yr
No. of Incubators	1.0	#
% Eggs not hatched (Losses)	20%	%
Total Quantity of Chicks Produced Annually	1,360,000.00	#/Yr
Thermal Energy Requirement (per chick)	310	BTU/Chick
Thermal Energy Requirement (per chick)	327	KJ/Chick
Total Annual Thermal Energy Requirement	556,017	MJ/Yr

Table A-12: Geothermal Milk Processing Technical Assumptions

TECHNICAL INPUTS	Value	Units
Quantity of Fresh Milk Processed	120,000	Ltr/Day
Initial milk temperature	20	oC
Final Process temperature	70	oC
Duration of Pasteurization	5.0	Hrs/Batch
Heat transfer rate	1,345	KJ/s
Heat transfer rate	4,842,000	KJ/hr
Daily Thermal Energy Requirement	24,210.00	MJ/Day
No. of Heat Exchangers Required	5.00	#
Plant Op Time	6	Days/Week
Plant Op Time	50	Weeks/Yr
No. of Operating Days per Year	300.0	Days/Yr
Annual Milk Pasteurization	36,000,000.00	Ltr/Yr
Annual Thermal Energy Requirement	7,263,000.00	MJ/Yr

2) Thermal Energy Requirements

Tables **A13-A19** below present the assumptions for the thermal energy requirements of the analyzed geothermal direct-use drying applications based on the assumed production levels.

Table A-13: Thermal Energy Requirements for Fish Drying

Quantity of Heat Required (Fish Drying)	
Temp of the product being dried (oC)	20.0
Temp of air from heat exchanger (oC)	52.0
Average temperature (oC)	36.00
Latent heat of evaporation (KJ/kg)	2,415
Quantity of heat (energy) required (kJ/Yr)	563,553,452.00
Quantity of heat (energy) required (kJ/s)	47.44

Table A-14: Thermal Energy Requirements for Fruit Drying

Quantity of Heat Required (Fruit Drying)	
Temp of the product being dried (oC)	24.0
Temp of air from heat exchanger (oC)	60.0
Average temperature (oC)	42.00
Latent heat of evaporation (KJ/kg)	2,401
Quantity of heat (energy) required (kJ/Yr)	504,910,748.70
Quantity of heat (energy) required (kJ/s)	34.06

Table A-15: Thermal Energy Requirements for Vegetable Drying

Quantity of Heat Required (Vegetable Drying)	
Temp of the product being dried (oC)	19.5
Temp of air from heat exchanger (oC)	50.0
Average temperature (oC)	34.75
Latent heat of evaporation (KJ/kg)	2,418
Quantity of heat (energy) required (kJ/Yr)	1,137,878,612.81
Quantity of heat (energy) required (kJ/s)	105.36

Table A-16: Thermal Energy Requirements for Rice Drying

Quantity of Heat Required (Rice Drying)	
Temp of the product being dried (oC)	25.0
Temp of air from heat exchanger (oC)	54.0
Average temperature (oC)	39.50
Latent heat of evaporation (KJ/kg)	2,407
Quantity of heat (energy) required (kJ/Yr)	604,554,503.44
Quantity of heat (energy) required (kJ/s)	174.93

Table A-17: Thermal Energy Requirements for Pyrethrum Drying

Quantity of Heat Required (Pyrethrum Drying)	
Temp of the product being dried (oC)	18.0
Temp of air from heat exchanger (oC)	50.0
Average temperature (oC)	34.00
Latent heat of evaporation (KJ/kg)	2,420
Quantity of heat (energy) required (kJ/Yr)	197,465,351.23
Quantity of heat (energy) required (kJ/s)	10.05

Table A-18: Thermal Energy Requirements for Tea Processing

Quantity of Heat Required (Tea Drying)	
Temp of the product being dried (oC)	21.5
Temp of air from heat exchanger (oC)	100.0
Average temperature (oC)	60.75
Latent heat of evaporation (KJ/kg)	2,357
Quantity of heat (energy) required (kJ/Yr)	23,379,548,333.88
Quantity of heat (energy) required (kJ/s)	1,082.39

Table A-19: Thermal Energy Requirements for Tobacco Curing

Quantity of Heat Required (Tobacco Curing)	
Temp of the product being dried (oC)	25.0
Temp of air from heat exchanger (oC)	50.0
Average temperature (oC)	37.5
Latent heat of evaporation (KJ/kg)	2,412
Quantity of heat (energy) required (kJ/Yr)	5,144,411,382.86
Quantity of heat (energy) required (kJ/s)	280.42

3) Revenue Assumptions

Tables A20-A28 present the assumptions related to pricing (local and export) of dried fish, fruits, vegetables, pyrethrum and rice produced by the plants/facilities as well as the annual price escalation. **Table A-24** presents the assumptions on ticket pricing and annual price escalation for a geothermal spa.

Table A-20: Geothermal Fish Drying Plant Revenue Assumptions (Rwanda)

REVENUE	USD
Price of Dry Fish - Local (USD/Kg)	6.25
Price of Dry Fish - Export (USD/Kg)	11.05
% of Dry Fish Sold Locally	50%
% of Dry Fish Exported	50%
Price Escalation (Annual)	1%

Table A-21: Geothermal Fish Drying Plant Revenue Assumptions (Ethiopia)

REVENUE	USD
Price of Dry Fish - Local (USD/Kg)	8.09
Price of Dry Fish - Export (USD/Kg)	11.05
% of Dry Fish Sold Locally	50%
% of Dry Fish Exported	50%
Price Escalation (Annual)	1%

Table A-22: Geothermal Fish Drying Plant Revenue Assumptions (Tanzania)

REVENUE	USD
Price of Dry Fish - Local (USD/Kg)	5.63
Price of Dry Fish - Export (USD/Kg)	11.05
% of Dry Fish Sold Locally	50%
% of Dry Fish Exported	50%
Price Escalation (Annual)	1%

Table A-23: Geothermal Fish Drying Plant Revenue Assumptions (Uganda)

REVENUE	USD
Price of Dry Fish - Local (USD/Kg)	6.78
Price of Dry Fish - Export (USD/Kg)	11.05
% of Dry Fish Sold Locally	50%
% of Dry Fish Exported	50%
Price Escalation (Annual)	1%

Table A-24: Geothermal Fruit Drying Plant Revenue Assumptions

REVENUE	USD
Price of Dry Fruit - Local (USD/Kg)	6.46
Price of Dry Fruit - Export (USD/Kg)	9.73
% of Dry Fruit Sold Locally	50%
% of Dry Fruit Exported	50%
Price Escalation (Annual)	1%

Table A-25: Geothermal Vegetable Drying Plant Revenue Assumptions[13]

REVENUE	USD
Price of Dry Veg - Local (USD/Kg)	3.69
Price of Dry Veg - Export (USD/Kg)	3.69
% of Dry Veg Sold Locally	50%
% of Dry Veg Exported	50%
Price Escalation (Annual)	1%

Table A-26: Geothermal Pyrethrum Drying Plant Revenue Assumptions[14]

REVENUE	USD
Price of Dry Pyrethrum - Local (USD/Kg)	3.46
Price of Dry Pyrethrum - Export (USD/Kg)	3.46
% of Dry Pyrethrum Sold Locally	50%
% of Dry Pyrethrum Exported	50%
Price Escalation (Annual)	1%

Table A-27: Geothermal Rice Drying Plant Revenue Assumptions

REVENUE	USD
Price of Dry Rice - Local (USD/Kg)	1.36
Price of Dry Rice - Export (USD/Kg)	-
% of Dry Rice Sold Locally	100%
% of Dry Rice Exported	0%
Price Escalation (Annual)	1%

Table A-28: Geothermal Spa Revenue Assumptions

REVENUE	USD
Ticket Price - Local Adults (USD)	5.82
Ticket Price - Local Children (USD)	2.91
Ticket Price - Resi Foreign Adults (USD)	11.64
Ticket Price - Resi Foreign Children (USD)	6.79
Ticket Price - Non-Resi Foreign Adults (USD)	19.40
Ticket Price - Non-Resi Foreign Children (USD)	10.19
% Local Adults	20%
% Local Children	15%
% Resi Foreign Adults	20%
% Resi Foreign Children	15%
% Non-Resi Foreign Adults	15%
% Non-Resi Foreign Children	15%
Price Escalation (Annual)	1%

[13] An average local and export price of $3.69 was assumed.
[14] An average local and export price of $3.46 was assumed.

4) Sources of Funds

Geothermal projects by nature are capital intensive and are usually financed by a combination of equity and debt. The financial analysis assumes that the projects will be financed with 30% equity and 70% debt as shown in **Tables A29-A** No grants have been assumed as there is no indication of the availability of grants for the analyzed projects.

Table A-29: Geothermal Fish Drying Plant Sources of Funds (Rwanda)

SOURCES	% of Total	$
Senior Debt	70%	188,045
Equity	30%	80,591
Grants/Rebate	0%	-
TOTAL	100.00%	268,636

Table A-30: Geothermal Fish Drying Plant Sources of Funds (Djibouti)

SOURCES	% of Total	$
Senior Debt	70%	185,129
Equity	30%	79,341
Grants/Rebate	0%	-
TOTAL	100.00%	264,470

Table A-31: Geothermal Fish Drying Plant Sources of Funds (Ethiopia)

SOURCES	% of Total	$
Senior Debt	70%	194,563
Equity	30%	83,384
Grants/Rebate	0%	-
TOTAL	100.00%	277,947

Table A-32: Geothermal Fish Drying Plant Sources of Funds (Kenya)

SOURCES	% of Total	$
Senior Debt	70%	188,320
Equity	30%	80,709
Grants/Rebate	0%	-
TOTAL	100.00%	269,029

Table A-33: Geothermal Fish Drying Plant Sources of Funds (Tanzania)

SOURCES	% of Total	$
Senior Debt	70%	185,887
Equity	30%	79,666
Grants/Rebate	0%	-
TOTAL	100.00%	265,553

Table A-34: Geothermal Fish Drying Plant Sources of Funds (Uganda)

SOURCES	% of Total	$
Senior Debt	70%	186,067
Equity	30%	79,743
Grants/Rebate	0%	-
TOTAL	100.00%	265,810

Table A-35: Geothermal Fruit Drying Plant Sources of Funds (Uganda)

SOURCES	% of Total	$
Senior Debt	70%	193,767
Equity	30%	83,043
Grants/Rebate	0%	-
TOTAL	100.00%	276,810

Table A-36: Geothermal Fruit Drying Plant Sources of Funds (Djibouti)

SOURCES	% of Total	$
Senior Debt	70%	192,829
Equity	30%	82,641
Grants/Rebate	0%	-
TOTAL	100.00%	275,470

Table A-37: Geothermal Fruit Drying Plant Sources of Funds (Ethiopia)

SOURCES	% of Total	$
Senior Debt	70%	202,263
Equity	30%	86,684
Grants/Rebate	0%	-
TOTAL	100.00%	288,947

Table A-38: Geothermal Fruit Drying Plant Sources of Funds (Kenya)

SOURCES	% of Total	$
Senior Debt	70%	196,020
Equity	30%	84,009
Grants/Rebate	0%	-
TOTAL	100.00%	280,029

Table A-39: Geothermal Vegetable Drying Plant Sources of Funds (Ethiopia)

SOURCES	% of Total	$
Senior Debt	70%	203,480
Equity	30%	87,206
Grants/Rebate	0%	-
TOTAL	100.00%	290,686

Table A-40: Geothermal Vegetable Drying Plant Sources of Funds (Djibouti)

SOURCES	% of Total	$
Senior Debt	70%	189,329
Equity	30%	81,141
Grants/Rebate	0%	-
TOTAL	100.00%	270,470

Table A-41: Geothermal Vegetable Drying Plant Sources of Funds (Kenya)

SOURCES	% of Total	$
Senior Debt	70%	194,116
Equity	30%	83,193
Grants/Rebate	0%	-
TOTAL	100.00%	277,309

Table A-42: Geothermal Vegetable Drying Plant Sources of Funds (Rwanda)

SOURCES	% of Total	$
Senior Debt	70%	193,703
Equity	30%	83,016
Grants/Rebate	0%	-
TOTAL	100.00%	276,719

Table A-43: Geothermal Vegetable Drying Plant Sources of Funds (Tanzania)

SOURCES	% of Total	$
Senior Debt	70%	190,466
Equity	30%	81,628
Grants/Rebate	0%	-
TOTAL	100.00%	272,094

Table A-44: Geothermal Vegetable Drying Plant Sources of Funds (Uganda)

SOURCES	% of Total	$
Senior Debt	70%	190,736
Equity	30%	81,744
Grants/Rebate	0%	-
TOTAL	100.00%	272,479

Table A-44: Geothermal Pyrethrum Drying Plant Sources of Funds

SOURCES	% of Total	$
Senior Debt	70%	206,016
Equity	30%	88,293
Grants/Rebate	0%	-
TOTAL	100.00%	294,309

Table A-45: Geothermal Rice Drying Plant Sources of Funds

SOURCES	% of Total	$
Senior Debt	70%	370,167
Equity	30%	158,643
Grants/Rebate	0%	-
TOTAL	100.00%	528,810

Table A-46: Geothermal Spa Sources of Funds (Djibouti)

SOURCES	% of Total	$
Senior Debt	70%	617,190
Equity	30%	264,510
Grants/Rebate	0%	-
TOTAL	100.00%	881,700

Table A-47: Geothermal Spa Sources of Funds (Ethiopia)

SOURCES	% of Total	$
Senior Debt	70%	692,662
Equity	30%	296,855
Grants/Rebate	0%	-
TOTAL	100.00%	989,517

Table A-48: Geothermal Spa Sources of Funds (Tanzania)

SOURCES	% of Total	$
Senior Debt	70%	623,253
Equity	30%	267,108
Grants/Rebate	0%	-
TOTAL	100.00%	890,362

Table A-49: Geothermal Spa Sources of Funds (Uganda)

SOURCES	% of Total	$
Senior Debt	70%	624,692
Equity	30%	267,725
Grants/Rebate	0%	-
TOTAL	100.00%	892,417

Table A-50: Geothermal Tea Processing Sources of Funds

SOURCES	% of Total	$
Senior Debt	70%	82,950
Equity	30%	35,550
Grants/Rebate	0%	-
TOTAL	100.00%	118,500

Table A-51: Geothermal Tobacco Curing Sources of Funds

SOURCES	% of Total	$
Senior Debt	70%	341,950
Equity	30%	146,550
Grants/Rebate	0%	-
TOTAL	100.00%	488,500

Table A-52: Geothermal Greenhouse Heating Sources of Funds (Tanzania)

SOURCES	% of Total	$
Senior Debt	70%	82,950
Equity	30%	35,550
Grants/Rebate	0%	-
TOTAL	100.00%	118,500

Table A-53: Geothermal Greenhouse Heating Sources of Funds (Ethiopia and Kenya)

SOURCES	% of Total	$
Senior Debt	70%	320,950
Equity	30%	137,550
Grants/Rebate	0%	-
TOTAL	100.00%	458,500

Table A-54: Geothermal Chicken Hatchery Sources of Funds

SOURCES	% of Total	$
Senior Debt	70%	68,950
Equity	30%	29,550
Grants/Rebate	0%	-
TOTAL	100.00%	98,500

Table A-55: Geothermal Milk Processing Sources of Funds

SOURCES	% of Total	$
Senior Debt	70%	124,950
Equity	30%	53,550
Grants/Rebate	0%	-
TOTAL	100.00%	178,500

5) Debt Assumptions

Tables A56-A61 present the project debt assumptions for each of the six countries. It is assumed that the debt for all the projects will be amortized annually over 10 years using income generated or cost savings.

Table A-56: Djibouti Debt Inputs

SENIOR DEBT	
All-in Interest Rate p.a	11.3%
Term (Years)	10

Table A-57: Ethiopia Debt Inputs

SENIOR DEBT	
All-in Interest Rate p.a	14.5%
Term (Years)	10

Table A-58: Kenya Debt Inputs

SENIOR DEBT	
All-in Interest Rate p.a	12.0%
Term (Years)	10

Table A-59: Rwanda Debt Inputs

SENIOR DEBT	
All-in Interest Rate p.a	16.7%
Term (Years)	10

Table A-60: Tanzania Debt Inputs

SENIOR DEBT	
All-in Interest Rate p.a	16.9%
Term (Years)	10

Table A-61: Uganda Debt Inputs

SENIOR DEBT	
All-in Interest Rate p.a	23.1%
Term (Years)	10

6) Taxes

Tables A62-A67 present the corporate income tax assumptions for each of the six countries.

Table A-62: Djibouti Tax Assumptions[15]

TAXES	
Tax Rate (% pa)	25%

Table A-63: Ethiopia Tax Assumptions[16]

TAXES	
Tax Rate (% pa)	30%

Table A-64: Kenya Tax Assumptions[17]

TAXES	
Tax Rate (% pa)	25%

Table A-65: Rwanda Tax Assumptions[18]

TAXES	
Tax Rate (% pa)	30%

Table A-66: Tanzania Tax Assumptions[19]

TAXES	
Tax Rate (% pa)	30%

Table A-67: Uganda Tax Assumptions[20]

TAXES	
Tax Rate (% pa)	30%

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[17] Maina, G., "Kenya passes corporate tax rate cut, modifies turnover tax and withholding tax," MNE Tax, (April 29, 2020): https://mnetax.com/kenya-passes-corporate-tax-rate-cut-modifies-turnover-tax-other-measures-38395; and https://www.bdo-ea.com/en-gb/microsites/doing-business-and-investing-in-kenya/tax/page-elements/taxation-in-kenya/corporate-tax#:~:text=The%20current%20corporate%20tax%20rate,Kenya%20is%20taxed%20at%2037.5%25
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[20] "Uganda: Taxes on corporate income," PwC, (28 January 2021): https://taxsummaries.pwc.com/uganda/corporate/taxes-on-corporate-income#:~:text=The%20income%20tax%20rate%20applicable,tax%20applies%20; and https://www.gtuganda.co.ug/globalassets/_markets_/uga/media/doing_business_in_uganda_taxation.pdf

7) Depreciation

Tables **A68-A95** include assumptions for the depreciation of the analyzed geothermal direct use projects. The plants/facilities will be depreciated at a book and tax depreciation rate of 4% per year respectively.

Table A-68: Geothermal Fish Drying Plant Depreciation Inputs (Rwanda)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	268,636
Salvage Value	-

Table A-69: Geothermal Fish Drying Plant Depreciation Inputs (Djibouti)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	264,470
Salvage Value	-

Table A-70: Geothermal Fish Drying Plant Depreciation Inputs (Ethiopia)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	277,947
Salvage Value	-

Table A-71: Geothermal Fish Drying Plant Depreciation Inputs (Kenya)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	269,029
Salvage Value	-

Table A-72: Geothermal Fish Drying Plant Depreciation Inputs (Tanzania)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	265,553
Salvage Value	-

Table A-73: Geothermal Fish Drying Plant Depreciation Inputs (Uganda)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	265,810
Salvage Value	-

Table A-74: Geothermal Fruit Drying Plant Depreciation Inputs (Uganda)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	276,810
Salvage Value	-

Table A-75: Geothermal Fruit Drying Plant Depreciation Inputs (Djibouti)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	275,470
Salvage Value	-

Table A-76: Geothermal Fruit Drying Plant Depreciation Inputs (Ethiopia)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	288,947
Salvage Value	-

Table A-77: Geothermal Fruit Drying Plant Depreciation Inputs (Kenya)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	280,029
Salvage Value	-

Table A-78: Geothermal Vegetable Drying Plant Depreciation Inputs (Ethiopia)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	290,686
Salvage Value	-

Table A-79: Geothermal Vegetable Drying Plant Depreciation Inputs (Djibouti)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	270,470
Salvage Value	-

Table A-80: Geothermal Vegetable Drying Plant Depreciation Inputs (Kenya)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	277,309
Salvage Value	-

Table A-81: Geothermal Vegetable Drying Plant Depreciation Inputs (Rwanda)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	276,719
Salvage Value	-

Table A-82: Geothermal Vegetable Drying Plant Depreciation Inputs (Tanzania)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	272,094
Salvage Value	-

Table A-83: Geothermal Vegetable Drying Plant Depreciation Inputs (Uganda)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	272,479
Salvage Value	-

Table A-84: Geothermal Pyrethrum Drying Plant Depreciation Inputs

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	294,309
Salvage Value	-

Table A-85: Geothermal Rice Drying Plant Depreciation Inputs

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	528,810
Salvage Value	-

Table A-86: Geothermal Spa Depreciation Inputs (Djibouti)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	881,700
Salvage Value	-

Table A-87: Geothermal Spa Depreciation Inputs (Ethiopia)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	989,517
Salvage Value	-

Table A-88: Geothermal Spa Depreciation Inputs (Tanzania)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	890,362
Salvage Value	-

Table A-89: Geothermal Spa Depreciation Inputs (Uganda)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	892,417
Salvage Value	-

Table A-90: Geothermal Tea Processing Depreciation Inputs

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	118,500
Salvage Value	-

Table A-91: Geothermal Tobacco Curing Depreciation Inputs

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	488,500
Salvage Value	-

Table A-92: Geothermal Greenhouse Heating Depreciation Inputs (Tanzania)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	118,500
Salvage Value	-

Table A-93: Geothermal Greenhouse Heating Depreciation Inputs (Ethiopia and Kenya)

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	458,500
Salvage Value	-

Table A-94: Geothermal Chicken Hatchery Depreciation Inputs

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	98,500
Salvage Value	-

Table A-95: Geothermal Milk Processing Depreciation Inputs

DEPRECIATION	
Average Dep Life (Yrs)	25
Depreciable Cost	178,500
Salvage Value	-

8) Labor Assumptions

Tables A96-A101 present the assumptions for labor requirements for the operation of the applications analyzed as greenfield projects.

Table A-96: Geothermal Fish Drying Plant Labor Inputs

Plant Labor	
No. of Kg per batch per Plant Labor	200
Plant Labor reqd per shift	5.0
Shifts/day	1
Hrs/shift	12
Plant Op Time (Days/Week)	6
Plant Op Time (Weeks/Yr)	50
Man Hrs/day	60
Man Hrs/Yr	18,000

Table A-97: Geothermal Fruit Drying Plant Labor Inputs

Plant Labor	
No. of Kg per dryer batch per Labor	200
Plant Labor reqd per dryer batch	5.0
Batches/day/dryer	2
Hrs/Batch	11
Plant Op Time (Days/Week)	6
Plant Op Time (Weeks/Yr)	39
Total Man Hrs/day	110.0
Total Man Hrs/Yr	25,740

Table A-98: Geothermal Vegetable Drying Plant Labor Inputs

Plant Labor	
No. of Kg per dryer batch per Labor	200
Plant Labor reqd per dryer batch	5.0
Batches/day/dryer	2
Hrs/Batch	7
Plant Op Time (Days/Week)	6
Plant Op Time (Weeks/Yr)	50
Total Man Hrs/day	70.0
Total Man Hrs/Yr	21,000

Table A-99: Geothermal Pyrethrum Drying Plant Labor Inputs

Plant Labor	
No. of Kg per dryer batch per Labor	100
Plant Labor reqd per dryer batch	10.0
Batches/day/dryer	1
Hrs/Batch	22
Plant Op Time (Days/Week)	6
Plant Op Time (Weeks/Yr)	43
Total Man Hrs/day	220.0
Total Man Hrs/Yr	57,200

Table A-100: Geothermal Rice Drying Plant Labor Inputs

Plant Labor	
No. of Kg per dryer batch per Labor	500
Plant Labor reqd per dryer batch	10.0
Batches/day/dryer	2
Hrs/Batch	9
Plant Op Time (Days/Week)	6
Plant Op Time (Weeks/Yr)	10
Total Man Hrs/day	540.0
Total Man Hrs/Yr	32,400

Table A-101: Geothermal Spa Labor Inputs

Plant Labor	
No. of Spa Labor per Visitor	0.0004
Spa Labor reqd per shift	6.0
Shifts/day	2
Hrs/shift	6
Spa Op Time (Days/Week)	7
Spa Op Time (Weeks/Yr)	47
Man Hrs/day	72
Man Hrs/Yr	23,688

9) Payroll Assumptions

Tables A102-A107 present the assumptions for payroll expenses for each of the six countries.

Table A-102: Djibouti Payroll Inputs

Payroll	Y/N	US$/yr	US$/yr
CEO	N	19,759	-
CFO/Accountant	Y	7,486	7,486
Spa Manager	Y	5,321	5,321
Asst. Manager	N	-	-
Sales & Marketing Manager	Y	5,321	5,321
Sales Reps	N	-	-
Other 1	N	-	-
Other 2	N	-	-
TOTAL			18,127

Table A-103: Kenya Payroll Inputs

Payroll	Y/N	US$/yr	US$/yr
CEO	N	18,265	-
CFO/Accountant	Y	7,959	7,959
Station/Plant Manager	Y	4,893	4,893
Asst. Manager	N	-	-
Sales & Marketing Manager	Y	4,893	4,893
Sales Reps	N	-	-
Other 1	N	-	-
Other 2	N	-	-
TOTAL			17,745

Table A-104: Ethiopia Payroll Inputs

Payroll	Y/N	US$/yr	US$/yr
CEO	N	6,119	-
CFO/Accountant	Y	2,992	2,992
Station/Plant Manager	Y	1,630	1,630
Asst. Manager	N	-	-
Sales & Marketing Manager	Y	1,865	1,865
Sales Reps	N	-	-
Other 1	N	-	-
Other 2	N	-	-
TOTAL			6,487

Table A-105: Rwanda Payroll Inputs

Payroll	Y/N	US$/yr	US$/yr
CEO	N	18,226	-
CFO/Accountant	Y	7,270	7,270
Station/Plant Manager	Y	5,187	5,187
Asst. Manager	N	-	-
Sales & Marketing Manager	Y	5,149	5,149
Sales Reps	N	-	-
Other 1	N	-	-
Other 2	N	-	-
TOTAL			17,605

Table A-106: Tanzania Payroll Inputs

Payroll	Y/N	US$/yr	US$/yr
CEO	N	14,811	-
CFO/Accountant	Y	5,976	5,976
Station/Plant Manager	Y	5,717	5,717
Asst. Manager	N	-	-
Sales & Marketing Manager	Y	4,374	4,374
Sales Reps	N	-	-
Other 1	N	-	-
Other 2	N	-	-
TOTAL			16,067

Table A-107: Uganda Payroll Inputs

Payroll	Y/N	US$/yr	US$/yr
CEO	N	19,029	-
CFO/Accountant	Y	7,427	7,427
Station/Plant Manager	Y	5,237	5,237
Asst. Manager	N	-	-
Sales & Marketing Manager	Y	5,774	5,774
Sales Reps	N	-	-
Other 1	N	-	-
Other 2	N	-	-
TOTAL			18,438

10) Foreign Exchange Parameters

Tables A71-A76 present the currency conversion assumptions used in the financial model for each of the six countries.

For **Djibouti**, the United States Dollar (USD) to Djiboutian Franc (DJF) exchange rate is assumed to be 177.9, consistent with prevailing rates:

Table A-71: Djibouti Currency Conversion Assumptions

CURRENCY CONVERSION	
Local Currency	Dj franc
Local Currency Code	DJF
Exchng Rate (DJF/USD)	177.94

For **Ethiopia**, the USD to Ethiopian Birr (ETB) exchange rate is assumed to be 37.1, consistent with prevailing rates:

Table A-72: Ethiopia Currency Conversion Assumptions

CURRENCY CONVERSION	
Local Currency	Birr
Local Currency Code	ETB
Exchng Rate (ETB/USD)	37.1

For **Kenya**, the USD to Kenyan Shilling (KES) exchange rate is assumed to be 108.4, consistent with prevailing rates:

Table A-73: Kenya Currency Conversion Assumptions

CURRENCY CONVERSION	
Local Currency	K Shilling
Local Currency Code	KES
Exchng Rate (KES/USD)	108.4029

For **Rwanda**, the USD to Rwandan Franc (RWF) exchange rate is assumed to be 960.2, consistent with prevailing rates:

Table A-74: Rwanda Currency Conversion Assumptions

CURRENCY CONVERSION	
Local Currency	R franc
Local Currency Code	RWF
Exchng Rate (RWF/USD)	960.161116

For **Tanzania**, the USD to Tanzanian Shilling (TZS) exchange rate is assumed to be 2,309.1, consistent with prevailing rates:

Table A-75: Tanzania Currency Conversion Assumptions

CURRENCY CONVERSION	
Local Currency	T Shilling
Local Currency Code	TZS
Exchng Rate (TZS/USD)	2309.06

For **Uganda**, the USD to Ugandan Shilling (UGX) exchange rate is assumed to be 3689.1, consistent with prevailing rates:

Table A-76: Uganda Currency Conversion Assumptions

CURRENCY CONVERSION	
Local Currency	U Shilling
Local Currency Code	UGX
Exchng Rate (UGX/USD)	3689.09

APPENDIX: FINANCIAL MODEL

The consolidated financial models and comparative analysis (cost comparison) spreadsheets used to prepare **Section II** are enclosed separately as attachments to this report. All sources and assumptions for the analysis in **Section II** are detailed in the financial model.

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