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Kenyan Flower Industry – Potential for Renewable Energy

Subsector Analysis

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Currency

1 USD	=	KShs 85.80
1 €	=	KShs 116.30

Measurement

W	Watt	Wp	Watt peak	Wh	Watt hour
kW	Kilowatt	kWp	Kilowatt peak	kWh	Kilowatt hour
MW	Megawatt	MWp	Megawatt peak	MWh	Megawatt hour
GW	Gigawatt	GWp	Gigawatt peak	GWh	Gigawatt hour

List of Acronyms

CI1	Commercial & Industrial Electricity Tariff metered at 415V
CI2	Commercial & Industrial Electricity Tariff metered at 11,000 V
CI3	Commercial & Industrial Electricity Tariff metered at 33,000 V
DC	Domestic Consumer Electricity Tariff
DNI	Direct Normal Irradiance
ERC	Energy Regulatory Commission
GDP	Gross Domestic Product
GHI	Global Horizontal Irradiance
HPS	High Pressure Sodium
KFC	Kenya Flower Council
KPLC	Kenya Power Lighting Company
kVA	Kilo Volt Ampere
kVAR	Kilo Volt Ampere Reactive
kW	Kilowatt
kWh	Kilowatt hour
kWp	Kilowatt peak
LED	Light Emitting Diode
MoEP	Ministry of Energy and Petroleum
PF	Power Factor
PV	Photovoltaic
SC	Small Commercial Electricity Tariff
SpEC	Specific Energy Consumption

Disclaimer

This report was prepared in collaboration with Kenya Flower Council. We would like to express our special thanks to the flower farms Uhuru Flowers, Tambuzi, Olij, PJ Dave, Maasai Flowers, Harvest Flowers and Simbi Roses for their collaboration and sharing of their data for the success of this report.

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Executive Summary - Results at a glance

8 **Flower farms** were found to have already installed renewable energy plants. 3 of them solar PV, 1 farm has a combined solar PV and solar thermal system, 1 farm a solar thermal system only, 2 have installed biogas plants and 1 has a geothermal plant installed.

5-7 **kWh/m^2/day** solar radiation (Direct Normal Irradiance) can be achieved in the areas where flower farming takes place. All the farms can therefore take advantage of solar power to reduce their grid power consumption.

30 % **Grid displacement** or more can be achieved by solar PV installations without storage batteries. Once the net-metering regulation is passed, this number will increase, since net-metering would make larger systems that supply excess to the national grid more attractive.

5-7 % **Interest rates** local banks are asking for if the loans are denominated in foreign currency. Corporate finance facilities rather than project finance are used to fund the RE projects in flower farms. The loans were denominated in foreign currency either in Euros or US Dollars. This is common practice for flower farms since they receive their revenue in forex.

6-7 **Years payback** flower farms can be expecting when investing in solar PV with an assumption of tariff growth of 15-30 % over 10 years and project cost of about US$ 2,300 per kWp (at the time of installation in 2013).

2-3 **Hours running time** is the number of hours that the pilot biogas plants are running in each of the biogas pilot plants to supply water pumps. One set of 100 kW genset is located at PJ Dave and the other set of 55 kW is located at Simbi Roses.

1. Introduction

1.1 The Kenyan Flower Industry

Kenya's economy largely relies on the agricultural sector which contributes 22 % to the Gross Domestic Product (GDP). Around 3 % of national GDP comes from the horticulture subsector while 1.6 % comes from the flower industry. Horticulture is one of the top foreign exchange earners for the country, generating approximately US$ 1 billion annually. The current Kenya Flower Council (KFC) membership represents 50 % to 60 % of the flowers exported. The floriculture industry has recorded growth in volume and value of cut flowers exported every year (10,946 tonnes in 1988 compared to 86,480 tonnes in 2006 and 121,891 tonnes in 2011). The USAID-KHCP Horticulture Performance 2010-2012 Report [1] shows that in 2012, the Kenyan floriculture industry exported 123,511 tonnes valued at KSh 42.9 billion (US$ 0.5 billion). Kenya is the lead exporter of rose cut flowers to the European Union (EU) with a market share of about 38 %. Approximately 65 % of exported flowers are sold through the Dutch Auctions, although direct sales are growing. The main production areas are located around Lake Naivasha, Mt. Kenya, Nairobi, Thika, Kiambu, Athi River, Kajiado, Kitale, Nakuru, Kericho, Nyandarua, Trans Nzoia, Uasin Gishu and Eastern Kenya around Timau. The main cut flowers grown in Kenya are roses (53.6 %), Easter Lilies (26.5 %), Arabicum (4.1 %) Carnations (3.1 %) and Hypericum (1.98 %). Other flowers cultivated include amongst others, Gypsophilla, Lilies Eryngiums, Arabicum, Hypericum, Statice, and a range of summer flowers.

The industry continues to attract investors comprised of large, medium and small scale producers that have attained high management standards and have invested heavily in technical skills, production, logistics and marketing. The farmers utilize high levels of technology, for example, computerized drip irrigation and fertigation systems, computerized greenhouse ventilation systems, net shading, pre-cooling and cold storage facilities, grading and bouqueting, fertilizer recycling systems to prevent wastage, wetlands for waste water treatment, artificial lighting to increase day length, grading/packaging sheds, and refrigerated trucks have been adopted. It is in this spirit of efficiency improvement that many flower farms have had energy audits carried out in their farms with the additional aim of saving energy costs. A number of farms have adopted renewable energy as a way of improving the reliability of their energy supply and cutting down on long-term energy costs. The renewable energy technologies that have been adopted include:

- solar PV mounted on roofs or on the ground, some with sun tracking mechanisms
- solar thermal systems to provide hot water to warm the ground in order to speed up flower growth in the greenhouses particularly at night and to increase the propagation of nursery plants
- biogas plants using flower waste and cow dung
- some farms are currently undertaking wind measurements to ascertain resource availability.

Consequently, KFC with the support of the World Bank and the Ministry of Energy and Petroleum (MoEP) commissioned a feasibility study to determine to what extent the waste generated from flower farms can support electricity generation for individual farms. The pilot study was conducted on two flower farms: PJ Dave in Isinya and Simbi Roses in Thika. Preliminary results from the study indicate that 1 tonne of flower waste can generate 60-80 m^3 of biogas that leads to avoided electricity purchase of KSh 2,500 – 3,000 (US$ 29 - 35). This represents 20-30 % reduction of energy costs on smaller farms and about 10 % on larger farms. Moreover, a number of flower farms have already adopted renewable energy technologies such as solar PV (e.g. 72 kW_p in Uhuru flowers, 60 kW_p in Tambuzi and 100 kW_p ground mounted solar PV with sun tracking mechanism in TimaFlors in Timau), solar thermal (Bilashaka Flowers), a combination thereof (100 kW_p solar PV and 150 m^3 solar thermal at Olij Flowers in Naivasha) and geothermal (Oserian flowers).

Globally, a growth of 5 % in the flower industry is anticipated every year over the next five years. To be a part of this opportunity, Kenya is going to continue the expansion of the sector while focusing on improved productivity to counter increased costs of production and decreased returns on investments.

Due to the practice of greenhouse farming, flower production is an energy intensive activity. Energy is required for water pumping, lighting, refrigeration, heating, and for sanitary processes. As a result, the flower farms incur significant costs in meeting their energy needs. Energy costs account for 10-20 % of the total operating costs of the farms. Further, flower farms are required under national laws to meet high social and environmental standards. Against this backdrop, the Kenya Flower Council (KFC) has introduced a comprehensive internationally accredited auditing scheme. So far, 23 energy audits have been conducted through KFC. The results showed a high potential in saving electricity costs through utilization of solar energy and flower waste.

1.2 Scope of the Report

The present report focuses on the study of renewable energy potential in 23 selected flower farms for which energy audits have previously been carried out. It starts with a review of these audit reports and continues with the recommendations of the energy auditors. Then the report sets out an analysis of renewable energy projects already implemented on some farms, including an analysis of economic viability. An identification of further sites with potential for renewable energy integration, highlighting different technological options and their respective cost-benefit estimations is following. Finally, the report closes with conclusions and recommendations for commercial viability and financing options of renewable energy projects in Kenyan flower farms and their way forward.

2. Review of Energy Audit Reports

2.1 Audited Flower Farms: Geographical Location and Characteristics

Energy audits were carried out on 23 flower farms that are members of Kenya Flower Council. The flower farms are located in areas where the Direct Normal Irradiance (DNI) varies between 5.07-6.51 kWh/m^2/day [2]. Farms in these areas can take advantage of solar PV to reduce their grid dependency and solar water heating. The farms and their location are as indicated below:

Table 1: List of flower farms, their location and site characteristics

	Name of company	Location	Zone	Solar irradiation and other characteristics in the zone
1	Winchester Farm	Karen	Nairobi	DNI 5.79 kWh/m^2/day
2	Isinya	Kajiado	Athi River and Kajiado	DNI 5.79 kWh/m^2/day *(Dry zone; irrigation water is drawn from boreholes with high salinity)*
3	Wamu Investment	Embakasi		
4	Maasai Flowers	Kitengela		
5	Harvest Flowers	Athi River		
6	Highlands Plants	Nakuru	Nakuru	DNI 5.76 kWh/m^2/day
7	Carzan Flowers	Rongai		
8	Olnjorowa Farm (Mbegu Farm)	Naivasha	Naivasha	DNI 5.68 kWh/m^2/day
9	Live Wire Ltd.	Naivasha		
10	Maridadi Flowers	Naivasha		
11	Groove Ltd.	Naivasha		
12	Kudenga Ltd	Molo	Molo and Njoro	DNI 5.76 kWh/m^2/day
13	Xpressions Flora Ltd.	Njoro		
14	Desire Flora	Molo		
15	Countrywide Connections	Nanyuki	Nanyuki	DNI 6.51 kWh/m^2/day *(Cool temperatures suitable for solar PV due to high altitude)*
16	Tambuzi Ltd	Nanyuki		
17	Red Lands Roses Ltd.	Ruiru	Thika and Kiambu	DNI 5.97 kWh/m^2/day in Kiambu, DNI 5.68 kWh/m^2/day in Thika
18	Simbi Roses	Thika		
19	Black Petals ltd.	Kiambu		
20	Gatoka Ltd.	Gatunyu- Thika		
21	Kariki Ltd.	Thika		
22	Fairy Flowers	Limuru	Limuru	DNI 5.07 kWh/m^2/day
23	Terrasol Ltd.	Limuru		

Source: own compilation based on SWERA DNI NASA Low Resolution data [2]

2.2 Typical Energy Consumption Patterns

2.2.1 Key thermal loads

The farms that comprehend hot water supply are involved in seedling propagation. This includes PJ Dave, Isinya, Winchester Farm and Maasai Flowers. The hot water is used to warm the ambient temperature around the seedling beds to maintain a certain temperature within the seedbed. The higher temperature has the effect of increasing the rate of propagation and reduces the prevalence of diseases that attack the flowers. In all these audited farms there was no flow meter installed to measure the amount of hot water flowing through the propagation greenhouses. In fact, it is suitable to replace the kerosene and diesel currently used in hot water boilers with solar water heating. A number of farms (e.g. Bilashaka Flowers, Olij Flowers) are already adopting this idea keeping sufficient storage and insulation in mind.

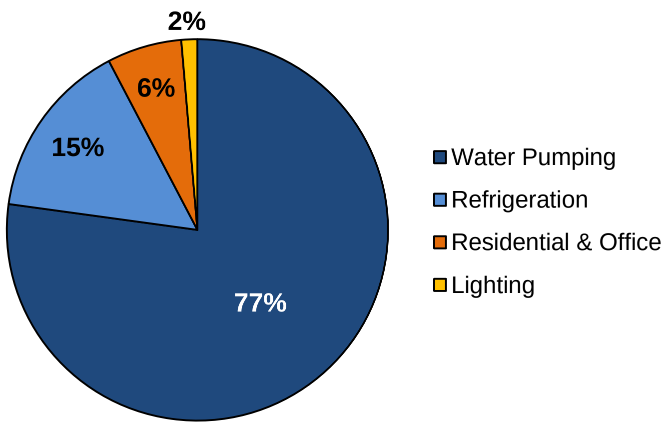
2.2.2 Key electrical loads

For the majority of farms (except those in the Athi River and Kajiado area), all the major operations including the water pumping and irrigation are carried out during daytime. For these farms only the cold rooms are running 24 hours. Water pumping and greenhouse fans (where existing) account for typically 60-80 % of the total energy consumption. The fans help in maintaining the required humidity in the greenhouses. The pumping is typically carried out for 6-12 hours depending on the farm. Some of the flower farms do not have access to close-by rivers or lakes, so that they are pumping water from man-made dams (e.g. Simbi Roses) or from boreholes (e.g. Maasai Flowers, Groove Ltd, Isinya). Sometimes it is necessary that the borehole pumping goes on throughout night. Especially in case of boreholes as water source the water has to pass through a reverse osmosis plant to reduce its mineral and salt content to make it suitable for the flower cultivation.

With all the electrical loads at the farms considered, the typical relative monthly electricity consumption can be presented as in the following two figures for a typical small (here: Groove Ltd.) and large farm (here: PJ Dave Ltd.). Usually there are no differences between weekdays and weekends evident as the flowers have to be supplied all week long.

The company Groove Ltd. which represents a typical small flower farm, operates for 10 hours a day between 8:00 am to 6:00 pm five days a week. It can be assumed that the borehole pump operates 12 hours a day, the distribution pump operates 8 hours a day and the cold room (refrigeration) operates 24 hours a day.

Figure 1: Typical electricity consumption in a small flower farm/Groove Ltd

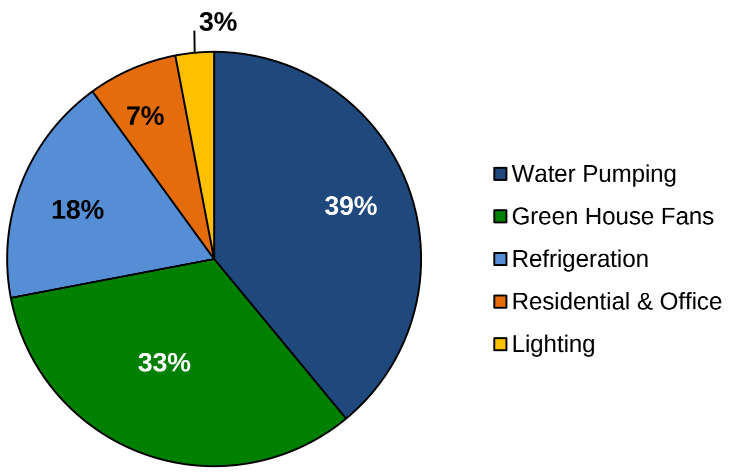


Type	Electricity consumption (in kWh/month)
Water Pumping	8,896 kWh
Refrigeration	1,746 kWh
Residential & Office	730 kWh
Lighting	156 kWh
Total	**11,528 kWh**

Source: own compilation based on Energy Audit Report., 2012 [3]

The company PJ Dave Ltd., which forms part of the PJ Group that manages four flower farms incorporated in Kenya as independent private limited liability companies, is a typical large flower farm. For PJ Dave, the electricity consumption was not given as relative consumption split in different loads. The following figure only presents the relative electrical load but not the electricity consumption. Thus it is not directly comparable to the graph shown for Groove Ltd.

Figure 2: Typical electrical loads in a large flower farm/PJ Dave Flowers Ltd



Type	Electrical Loads (in kW)
Water Pumping	420 kW
Green House Fans	348 kW
Refrigeration	195 kW
Residential & Office	71 kW
Lighting	35 kW
Total	**1,069 kW**

Source: own compilation based on Energy Audit Report., 2011 [4]

2.2.3 Typical load profiles

As described above, the flower farms do have different electricity consumptions in terms of quantity and frequency due to the different concepts of the farms (e.g. source and quality of the water). To get a better understanding of the exact electricity consumption over time, the author of this study gathered the load profiles of three representative flower farms in Kenia. For further information, the Renewable Energy Project Development Programme (pep@giz.de) can provide the raw data set. Below the specified load curves of the three flower farms, namely Simbi Roses, Maasai Flowers and Harvest Flowers, are shown.

2.2.3.1 Simbi Roses

Simbi Roses obtains its irrigation water of dams from where the water is pumped to a reservoir. This happens mainly throughout daytime. From the reservoir, irrigation and fertigation pumps are transporting the water to the greenhouses. As shown in the table below, the pumps generate the bulk of the daily load (67 %). Simbi Roses is not running its own nursery.

Table 2: Load distribution of Simbi Roses

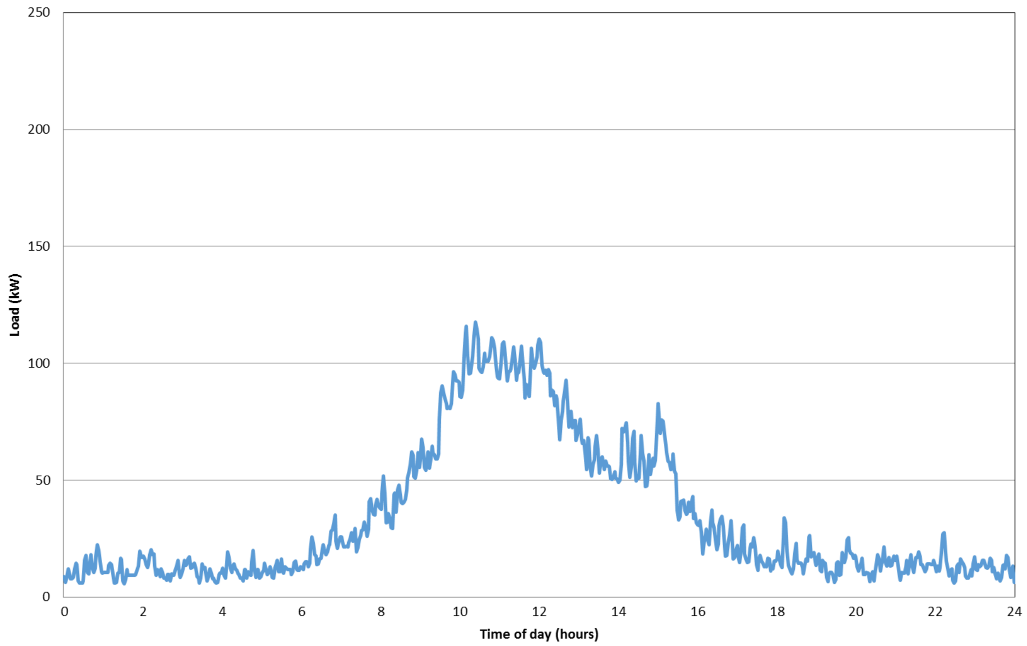
Unit	Load Distribution (%)
Lighting	9
Pumping	67
Refrigeration	13
Greenhouses	11

Source: own compilation based on Energy Audit Report., 2012 [5]

The load demand over the day is reflected in the load profile shown in the following figure. The data is obtained by measurements taken from 30th June to 7th July 2014 at Simbi Roses flower farm. It peaks in the afternoon, whereas for the remainder of the day and night the load stays relatively constant. This regular base load is attributed to the cold room compressors and evaporator fans as well as the lighting. The load curve of this dam feed farm which runs its pumps mainly during daytime, shows a typical midday peak.

Figure 3: Daily load profile for Simbi Roses

(dams as water source, pumps running during daytime)



Source: measurements obtained by Author

2.2.3.2 Maasai Flowers

The second flower farm whose load profile was observed is the Maasai Flowers farm. Maasai Flowers sources its irrigation water from boreholes. This water is continually – day and night – pumped from the boreholes. Due to insufficient water quality it requires purification before being usable in the greenhouses. This is achieved by means of a reverse osmosis plant, which also operates continually. From this purification plant the water is pumped to the greenhouses. Therefore two separate pumping systems are continually running. This explains the higher percentage to the load distribution by pumping (85 %) compared to Simbi Roses (67 %). Maasai Flowers is running an own nursery.

Table 3: Load distribution of Maasai Flowers

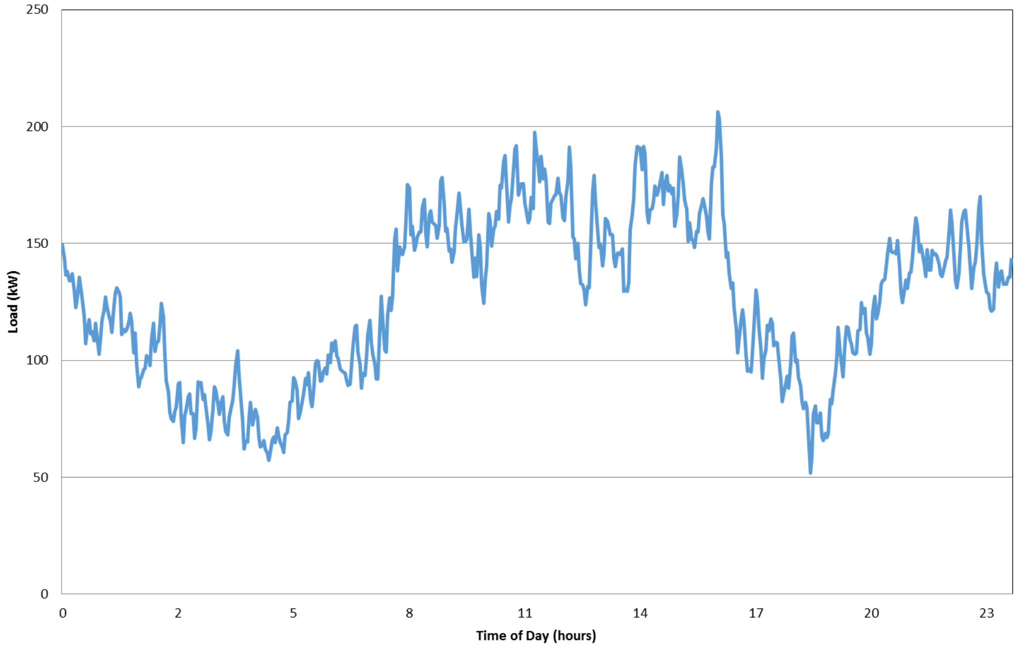
Unit	**Load Distribution** (%)
Lighting	1
Pumping	85
Refrigeration	14

Source: own compilation based on Energy Audit Report., 2012 [6]

The load profile of Maasai Flowers is given in the figure below. The cold room compressors and the fans as well as irrigation and fertigation pumps are operating 24 h a day. The comparably higher base load can be attributed to the continual sourcing of water from boreholes and the subsequently required purification as well as to the maintenance of the nursery. The higher fluctuation of the load profile also attracts attention. This can be explained by the following facts: Maasai has several boreholes and reverse osmosis plants. The nursery temperature also fluctuates depending on ambient temperature and the different temperature and humidity requirements of the different plants in the nursery. All these are reasons why the load profile of Maasai Flowers is fluctuating more than the one of other farms and was determined during 27th May and 1st of June 2014.

Figure 4: Daily load profile for Maasai Flowers

(boreholes as water source, purification required, pumps running day and night)



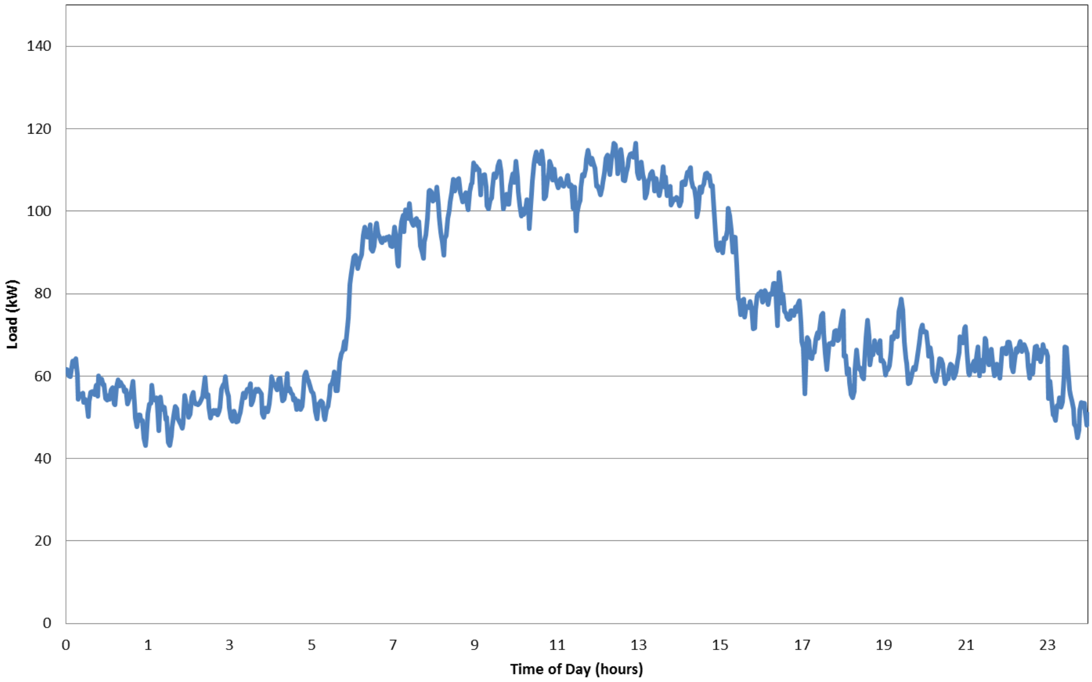
Source: measurements obtained by Author

2.2.3.3 Harvest Flowers

The third flower farm, namely Harvest Flowers, is sourcing its water partly from dams and partly from boreholes. The boreholes are used as a backup in case the river is not bearing enough water to feed the dams. In contrast to the borehole water, the river water requires no further purification. The pumping of the river water to the dams as well as the borehole pumping is running continuously. In case of borehole water supply, the water is subsequently sent to a reverse osmosis plant after pumping. The company-owned nursery is running day and night. These facts result in a recognisable base load of around 50kW which can be retraced in the figure below. The irrigation and fertigation pumps are only operating during daytime, resulting in the peak observed. The load profile of Harvest Flowers was determined during 11th and 18th July 2014 at the largest of three power meters.

Figure 5: Daily load profile for Harvest Flowers

(boreholes as water source, purification required, irrigation and fertigation pumps running during daytime, borehole and purification pumps day and night)



Source: measurements obtained by Author

2.3 Energy Expenditures, Electricity Tariffs and Consumer Categories

2.3.1 Energy expenditures per flower farm

The energy audits do not capture the load profile of the whole flower farm, because generally the auditor is interested in the equipment's energy efficiency rather than overall renewable energy potential. For this reason the farms audited do not include measurements of overall load profiles. The reports are also missing the thermal load requirements. It is known that hot water is used only at night in the seedling propagation units to heat the seedbeds. This water can be heated by solar thermal systems and then stored in a tank until it is required. Currently all three farms with propagation units among the audited farms use hot water boilers to supply the hot water using either diesel or kerosene. The records of diesel consumption contained in the audit reports do not differentiate between consumption in backup gensets, boilers and car fuel tanks.

There is a large variation in the Specific Energy Cost (SpEC) depending on the source and the quality of water being used and whether there is nursery propagation[1] or not. Some of the farms are pumping water from a stream, a river or lake, while others are pumping water from a borehole. In most cases the borehole water must be purified through a reverse osmosis plant due to its salinity. All these factors bring about different power consumptions and results in a SpEC varying between KSh 0.26 and 1.69 per stem (0.3 and 2 US cents).

[1] Nursery propagation involves heating the soil with warm water coming from a boiler.

Table 4: Summary of energy cost and Specific Energy Cost (SpEC) in each farm

	Name of company	**Electr. Tariff** (cate-gory)	**Annual Electrical Usage** (in kWh)	**Annual Cost for Electricity** (in KSh)	**Cost Per Unit** (in KSh/ kWh)	**Annual Cost for Diesel** (in KSh)	**Annual Cost for Kerosene** (in KSh)	**Annual Cost Total Energy** (in KSh)	**SpEC per 1,000 flower stems** (in KSh)
1	Isinya	CI1	1,586,436	27,373,536	17.25	8,679,108	3,824,496	39,877,140	1.04
2	Carzan Flowers	n/a	1,682,929	31,488,738	18.71	-	-	31,488,738	0.92
3	Maasai Flowers	CI1	895,320	17,369,208	19.40	-	13,247,325	30,616,533	0.89
4	Harvest Flowers	CI1	1,240,120	23,049,892	18.59	3,159,200	-	26,209,092	0.83
5	Winchester Farm	CI2 & SC	256,944	4,984,714	19.40	7,947,505	7,039,000	19,971,219	1.35
6	Red Lands Roses Ltd.	CI1	1,071,588	18,310,000	17.09	-	-	18,310,000	1.69
7	Olnjorowa Farm	CI1 & SC	841,536	15,658,432	18.61	1,003,890	-	16,662,322	0.45
8	Simbi Roses	Various	641,564	14,500,992	22.60	790,776	-	15,291,768	0.38
9	Maridadi Flowers	CI1	688,125	13,470,440	19.58	-	-	13,470,440	7.36
10	Black Petals Ltd.	CI1 & SC	673,739	12,219,789	18.14	810,800	-	13,030,589	0.64
11	Kudenga Ltd.	None	176,879	-	-	12,941,638	-	12,941,638	0.94
12	Xpressions Flora Ltd.	CI1	511,293	10,131,590	19.82	1,049,650	-	11,181,240	0.35
13	Live Wire Ltd.	SC	439,997	8,375,244	19.03	2,684,318	-	11,059,562	1.29
14	Desire Flora	CI1	688,064	10,900,044	15.84	-	-	10,900,044	0.63
15	Countrywide Connections	CI1	520,362	9,797,077	18.83	630,000	-	10,427,077	0.51
16	Gatoka Ltd.	Various	506,065	10,070,693	19.90	277,115	-	10,347,809	0.75
17	Kariki Ltd.	CI1 & SC	526,837	7,890,000	14.98	2,288,955	-	10,178,954	0.94
18	Tambuzi Ltd.	CI1 & SC	266,820	5,619,229	21.06	-	-	5,619,229	1.16
19	Terrasol Ltd.	SC	174,876	3,461,196	19.79	-	-	3,461,196	0.06
20	Highlands Plants	CI1	134,760	2,625,124	19.48	572,832	122,148	3,320,104	0.08 KSh/kg
21	Wamu Investment	DC	84,240	2,447,172	29.05	-	-	2,447,172	1.52 KSh/kg
22	Fairy Flowers	SC	74,928	1,815,015	24.22	-	-	1,815,015	0.09
23	Groove Ltd.	SC	82,814	1,321,240	15.95	-	-	1,321,240	0.26

Source: own compilation based on various energy audits

2.3.2 Increased Electricity tariffs as of July 2014

Table 5: New electricity tariffs in Kenya

Tariff	New Tariff Effective since July 2014 Charges (KSh)		
	Fixed charge	**Energy charge (per kWh)**	**Demand charge (per kVA)**
DC (Domestic, 240 V)	150	First 50kWh: 2.50 50 to 1,500kWh: 13.68 Thereafter: 21.57	n/a
SC (Small Commercial, 240 V)	150	14.00	n/a
CI1 (Commercial Industrial, 415 V)	2,000	9.45	800
CI2 (Commercial Industrial, 11 kV)	4,500	8.25	520
CI3 (Commercial Industrial, 33 kV)	5,500	7.75	270
CI4 (Commercial Industrial, 66 kV)	6,500	7.55	220
CI5 (Commercial Industrial, 132kV)	17,000	7.35	220

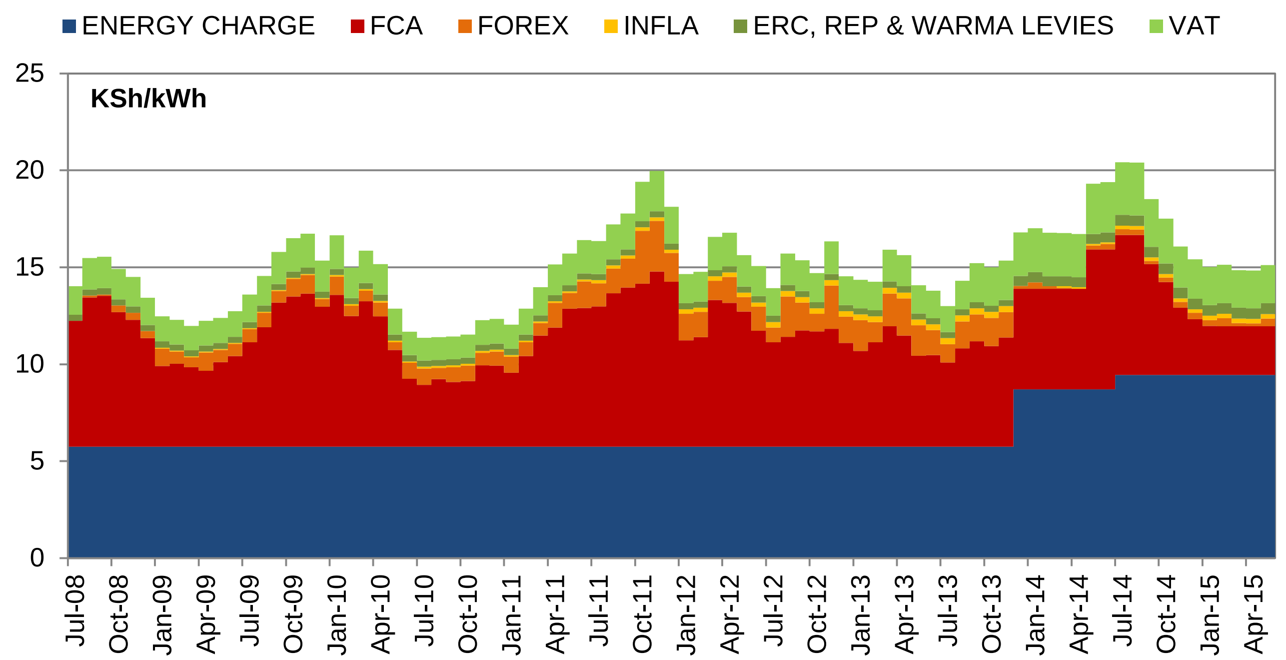
Source: own compilation based on Kenya Power data [7]

The tariffs that were used in the audit reports have been applicable since 1st July 2008. In late 2013, after several applications by Kenya Power, the Energy Regulatory Commission (ERC) agreed to an increase in the tariffs which have then been further been increased in July 2014. The new tariffs which are higher than previous ones are likely to favor increased adoption of RE projects since the unit cost of electricity that needs to be paid by the flower industry rises. Various tariffs ranging from Domestic Consumer (DC) to Commercial and Industrial (CI2) apply to the flower farms in Kenya. In addition to the above charges, the audit reports considered additional levies and taxes that need to be paid in Kenya, which consist of the following:

- Fuel cost charge adjustment (FCA)
- Foreign exchange rate fluctuation adjustment (FOREX)
- Inflation adjustment (INFLA)
- Rural Electrification Programme (REP) levy at 5 % of revenue from energy charge
- Energy Regulatory Commission (ERC) levy at 3 KSh/kWh
- Water Resources Management Authority (WARMA) levy at 6 KSh/kWh
- VAT at 16 % (except of inflation adjustment & levies)

Apart from an increase in the rate for the energy charge, there has also been an increase in VAT from 12 % to 16 % in 2013. Further, there is an additional levy called WARMA (Water Resources Management Authority) Levy charged at 6 KSh/kWh that has been included in the new tariff.

Figure 6: Electricity cost build-up for a CI1 consumer and its monthly evolution



Source: own compilation based on Kenya Power data [7]

The graph above does not include the costs for the demand charge which can be a significant amount of the total electricity bill and further increase the overall price to about 20 KSh/kWh.
The analysis in this report was based on the old tariffs because the new tariffs came into effect in December 2013 and July 2014 long after the actual energy audits were carried out.

2.3.3 Recommendations

There are a lot of variations in the unit price of electricity even among farms in the same tariff category due to differences in the demand charge. The flower farm Wamu Investment is obviously in the wrong tariff class (Domestic/DC), which explains their high unit price for electricity of 29 KSh/kWh (33.8 US cents per kWh). Some farms have even several meters in different tariff classes.

> For a number of farms it is advisable to consolidate the metering to a single tariff which can lead to a reduction of costs.

Some of the high consumers above 75,000 units per month should also consider being metered on CI2 where the rates are lower but where one must purchase the transformer from the utility company and be responsible for its maintenance. Such companies include Isinya, Harvest Flowers, Carzan Flowers and Red Lands Roses. Analysis must also address potential business risks arising from transformer outages. If the transformer is owned by Kenya Power, they carry out the maintenance and in case of an outage they can bring a spare transformer. All these responsibilities would shift to the consumer if the system owner purchases the transformer. For example at an average of 50,000 units per month and maximum demand of about 250 kVA the monthly saving is about KSh 113,766 (US$ 1,325.94) or approx. KSh 1.4 million (US$ 15,911) per annum merely by shifting from CI1 to CI2.

3. Recommended Energy Efficiency Measures from the Energy Audit Reports

3.1 Summary of the Energy Audit Recommendations

There is a large variation in energy saving recommendations depending on the auditor who did the energy audit. While there are common recommendations such as replacement of existing motors with energy efficient motors and lighting, there are also mentioned RE solutions such as solar PV and biogas from flower waste, variable speed drives (VSDs) to control irrigation pumps, replacement of inefficient capacitor banks and optimisation of water pumping systems. The energy audits focused mainly on the energy efficiency opportunities while renewable energy opportunities were only mentioned without further analysis. Whenever an attempt was done to size a RE plant, it was made without adequately determining the resource availability.

Table 6: Summary of the recommended energy efficiency measures and their frequencies

Recommended Energy Saving Measures	Frequency
Use of high efficiency motors/pumps	19
Use of LED lights	17
Cold room curtains (pre-cooling store)/PVC screen curtains/electric	13
Instituting an energy management system	10
Use of variable speed drives (VSDs)	8
Replacement of electromagnetic ballasts with electronic ballasts	8
Installation of 1 tonne (refrigeration unit)	6
Motor load assessment	4
Delivery truck operation	4
Use of T5 fluorescent	4
Amalgamation and tariff migration	4
Energy recovery cold well	3
Installation of timer or photo sensor	3
Replacement of capacitors	3
Boiler combustion efficiency	3
Use of soft starters	2
Replacement of cushions	2
Solar water heating (back-up for boiler)	2
Solar lighting (used during day and night)	2
Generation of electricity from decomposing organic matter	2
Power factor correction	2

Source: own compilation based on various energy audits

The energy efficiency opportunities available in the flower farms include the following[2]:

1) Institution of an energy management system that will provide the necessary focus and budget in order to continuously monitor available opportunities and track performance in energy efficiency. It will also improve the awareness of energy conservation among employees. Part of this energy management is to develop a companywide energy policy. This was a frequent recommendation made by almost every energy auditor. Most farms do not have an energy management system in place and no policy to guide the management of energy use. Under the current Energy Regulation 2012, companies are required to institute such a policy to guide the energy management in the organisation.

2) Replacing standard motors with energy efficient motors: From the summary above, replacement of standard motors with highly energy efficient motors was recommended in 19 out of the 23 farms. This is an energy conservation measure that can be implemented in all flower farms. The simple payback ranges between 2-4 years depending on the annual usage of the motor.

3) Use of variable speed drives particularly in the fertigation and irrigation pumps where a variable amount of water is required.

4) A number of motors were found to be either overloaded or significantly under-loaded leading to inefficiency. Motor load assessment has been recommended with the aim of rationalising the motor loads. Rationalisation of motors loading would ensure that they are appropriately loaded above 65 %.

5) Most auditors identified torn cold room curtains as a problem as these allow warm air to enter the cold room. This is a serious housekeeping issue which requires urgent attention whenever it occurs, since torn curtains can have a large impact on cold room power consumption.

6) Use of high efficiency lights to replace the fluorescent lights with magnetic ballasts which are the most common and the high pressure sodium and metal halides which are used for elongating the day light. In this case LED lights, T5 fluorescent fittings and replacement of existing electro-magnetic ballasts with electronic ones have been recommended. While this measure was recommended in 17 of the audit reports we suggest that all the farms should adopt this measure.

7) Consolidation of electricity metering so that one farm has only one meter and then to migrate to the next appropriate tariff which will be cheaper. In a number of farms there were several electricity meters which were on more expensive tariffs.

8) Power Factor Correction: A number of farms were found to be paying a power factor surcharge to the utility company either because of malfunctioning of the power factor correction capacitor banks or just not having sufficient capacitors. In several farms it was discovered that they were using energy inefficient capacitors whose specific power consumption per kVar was as high as 26 W/kVar. The resulting power loss is very high, as there are capacitors from manufacturers capable of achieving 2-3 W/kVar. Most auditors did not check the capacitors for power loss and hence this measure was only recommended in a few farms. Wherever it was recommended the payback was found to be less than a year. This is a measure that should be considered and adopted in all flower farms.

9) Energy conservation through irrigation pumping rationalisation: This was not examined by most auditors. In the few instances where it was considered, the irrigation pumping was found to be only 10 % efficient. By recommending the appropriate pumping to deliver the same amount of water daily with appropriate pressure head at the furthest places and avoiding throttling of pumps, a pumping efficiency of 65 % is achievable. This results in significant energy savings with a payback of less than one month. This is a measure that should be examined and adopted in all flower farms.

[2] Renewable Energy options for Flower Farms are explained in chapter 4 & 5.

10) A heat recovery system has been recommended to recover heat from the cold room refrigeration system. The heat recovered can be used to preheat the water for flower propagation in the nursery. A particular heat recovery system called the Eureka Permanent Transfer System (PTS) has been recommended for several farms and is capable of generating hot water between 50-60°C from refrigeration systems of 1 to 400 kW cooling loads. This requires further evaluation to determine if sufficient volumes of hot water can be generated to meet the farms' hot water requirements. The commercial viability of the PTS should be compared with a solar water heating system. The current law demands that 60 % of the hot water requirement should be supplied through a solar water heating system.

3.2 Recommendation: Switch to LED Lighting

General lighting used in the flower farms is provided by fluorescent lights with magnetic ballasts. However there is specialised lighting to extend the daylight time that some plants require. In this category there is extensive use of high-pressure sodium (HPS) lamps. The following farms use this kind of lamps which are very high consumers and could be replaced with appropriate LED floodlights:

Table 7: Distribution of high discharge lamps in various farms

Farm	Light	Wattage	Quantity
Maasai	HPS	70W	31
Winchester	HPS	125W	6
Red Lands Roses	HPS	70W	n/a
	Halogen	300W	n/a
Black Petals	HPS	400W	5
	Halogen	500W	2
Kudenga	HPS	400W	2
Live Wire	HPS	400W	162

Source: own compilation based on various energy audits

3.3 Recommendation: Use High Efficiency Electricity Motors

Below is a summary of the standard motors found in the farms that could be replaced with high energy efficient motors. There are about 195 motors in 15 farms. In four of the farms audited the auditors recommended the replacement of all standard motors with high efficiency motors without providing an inventory of the motor sizes involved. About 90 of these are between 15 kW and 110 kW and are good candidates for replacement with energy efficient ones. The smaller motors could be replaced whenever the motor windings get burnt. There is a large variation in number of hours of daily running. Any motor that is running for more than 12 hours daily should be replaced with an energy efficient one and leading to a possible payback between 3-4 years. Those running for 18 hours daily provide a simple payback of 2-3 years. This is an area where KFC members could collaborate to do joint procurement in order to take advantage of economies of scale.

Table 8: Distribution of standard motors in various farms

	Number of Motors of different sizes per location														
Size (in kW)	**110**	**93**	**55**	**45**	**37**	**35**	**30**	**26.5**	**22**	**18.5**	**15**	**13**	**11**	**<10**	**Total**
Isinya							1		5	2	3		13	18	42
Carzan Flowers															n/a
Maasai Flowers					2					3		1	6	2	14
Harvest Flowers			1						4	2	5		1	1	14
Winchester Farm				1							2		2	6	11
Red Lands Roses Ltd			1						1	1	4		1	11	19
Olnjorowa Farm				1			4		3			2	2	5	17
Simbi Roses	2		2		1		2				1				8
Maridadi Flowers															n/a
Black Petals Ltd.															n/a
Kudenga Ltd.			1			2			2		4			1	10
Xpressions Flora Ltd.										3	5			9	17
Live Wire Ltd.															n/a
Desire Flora					1			1		4	1			2	9
Countrywide Connections							2						2	2	6
Gatoka Ltd.		1	2			1	1		1						6
Kariki Ltd.															n/a
Tambuzi Ltd.									2	1				6	9
Terrasol Ltd.															n/a
Highlands Plants															n/a
Wamu Investment															n/a
Fairy Flowers														2	2
Groove Ltd.										1				10	11
TOTAL	**2**	**1**	**7**	**2**	**4**	**3**	**10**	**1**	**18**	**17**	**25**	**3**	**27**	**71**	**195**

Source: own compilation based on various energy audits

3.4 Status of Implementation

Out of the 23 flower farms that were audited only five farms have attempted to implement at least some of the measures that were recommended. The farms and what they have implemented are listed below:

Table 9: Energy efficiency measures implemented in various farms

Flower Farm	Measures Implemented
Countrywide	Replaced magnetic ballasts with electronic ballasts
Kudenga	Connected to the electricity grid and migrated from running on diesel generators
Simbi Roses	Eliminated sharp bends and commissioned biogas plant
Live Wire	Replaced refrigeration controls
Groove	Replaced magnetic ballasts with electronic ballasts on the T8 Fluorescent fittings

Source: information based on telephone interviews by the author

It should be noted that except for the measures implemented by Kudenga and Simbi Roses which have invested in grid connection and in setting up a biogas pilot project, the measures taken by the other farms involve minimal investment with limited impact on energy consumption. None of the remaining 18 farms have started implementation of measures recommended in the audit reports.

Findings: In general, it can be stated that there was very little uptake on the energy conservation measures recommended in the audit reports.

4. Renewable Energy Projects implemented in Flower Farms in Kenya

The renewable energy opportunities available in the flower farms include the following:

1) Power generation through solar PV:
The utilization of solar PV could offset the electricity bills, reduce dependence on the national grid and the adverse environmental effects of fossil fuel-powered generators. Uhuru Flowers and Tambuzi Farm that are currently operating with solar PV expressed their satisfaction with the investment and its operation. There is no maintenance required and the system is very reliable. Both are expecting the plant to break even in 5-6 years. The time until payback is reached depends on how the cost of electricity will evolve over the next years. If it increases, their payback period will drop and if it decreases then the payback period will extend.

2) Water heating through solar thermal:
Solar thermal can only be applied to those flower farms (i.e. PJ Dave, Isinya, Winchester Farm and Maasai Flowers) that are involved in seedling propagation. Their hot water supply could be generated by solar thermal collectors instead of the currently used kerosene boilers. The hot water is needed to warm up the ambient temperature around the seedling beds to maintain a certain temperature within the seedbed. This increases the rate of propagation and reduces the prevalence of diseases that attack the flowers. In all the farms that were audited there was no flow meter installed to measure the amount of hot water flowing through the propagation greenhouses. Olij Flowers has installed a 150 m^3 water storage tank for solar heated water. A number of farms are already adopting the replacement of kerosene and diesel boilers with solar heating systems keeping sufficient storage and insulation in mind.

3) Power generation through flower waste:
Biogas is a product of an anaerobic biological process which takes place without the impact of oxygen. It is a combustible gas which is produced when bacteria, in the absence of oxygen, decompose organic material. This process is called fermentation. Biogas comprises primarily methane and carbon dioxide. It is a high-energy, renewable gas that can be used to replace fossil fuels. Raw material for the production of biogas is very cheap because most of the required organic material is considered as waste material. In the flower farms the produced biogas from biodegradable flower waste can be used for power production in a biogas genset or in a gas boiler for thermal energy generation.
A pilot project in PJ Dave flower farm in Isinya has shown that it is possible to generate up to 80 kWh of electricity with 1 tonne of flower waste. Most flower farms are generating 3-7 tonnes of flower waste per day. That is equivalent to 240 kWh–560 kWh per day. This implies savings of KSh 1.6 M to KSh 3.6 M (US$ 18,650 to US$ 41,960) per annum, potentially leading to a reduction of 10-15 % of current energy costs. However, a comprehensive project evaluation is required to determine whether this is a viable option.

4) Power generation through Geothermal**:**
Oserian Flowers leased three geothermal wells from KenGen in 2003 [8]. Using these wells, they constructed a 2.0 MW plant to utilize fluid from the wells. The plant, which is supposed to provide electrical power for the farm’s operations, was commissioned in July 2004. Oserian who grows cut flowers for export is also utilizing steam from a 1.28 MW well to heat fresh water through heat exchangers, enrich CO_2 levels and to fumigate the soil. Through a system of loops hot geothermal fluid heats fresh water which is used as a heat transport medium to the greenhouse. Greenhouse heating assists in controlling relative humidity within the greenhouse especially in the early morning hours when humidity tends to rise to about 100 %. Reducing relative humidity to below 85 % eliminates fungal infection and hence eliminates the use of chemical fungicides. Heated water is also used to sterilize the fertilized water reducing fertilizer wastage and hence reducing cost. Carbon dioxide from the well is piped to the greenhouses in order to enhance photosynthesis.

Below an overview of renewable energy projects already installed at different flower farms is listed:

Table 10: Overview of RE installations at flower farms

Flower Farm	Type of RE installed	Installed Capacity	Grid displace-ment	Developer & Installation	Financing	Commissioned
Uhuru Flowers	PV	72 kW_p	~30 %	Azimuth Power / East African Solar	Corporate finance	Feb 2013
Tambuzi Ltd.	PV	60 kW_p	~30 %	Chloride Exide	Corporate finance	Sept 2013
Timaflor Ltd.	PV (1-way tracking)	100 kW_p	n/a	Azimuth Power	n/a	2013
Olij Flowers	PV & Solar Thermal	100 kW_p & 180 m^2 thermal collectors	100 %	Van Zaal, Bosman Kenya Ltd., Hoogendoorn and Olij Flowers	n/a	Not commissioned by the time of writing
Bilashaka Flowers	Solar Thermal	n/a	n/a	n/a	n/a	2006
PJ Dave Ltd.	Biogas	125 kVA biogas generator	1.5 %	Pharma Engineers	1/3 corporate finance, 2/3 government grant	October 2013
Simbi Roses	Biogas	69 kVA biogas generator	0.9 %	Pharma Engineers	1/3 corporate finance, 2/3 government grant	May 2013
Oserian Flowers	Geothermal	2.0 MW power plant & 1.28 MW water heating	100 %	KenGen for steam well and another equipment supplier	Corporate finance	July 2004

Source: own compilation based on author's research and interviews

4.1 Licensing and Permitting

All the flower farms that have installed Solar PV or Biogas have installed systems below 100 kW. This is well within the range where permits and licenses are not required according to the Kenyan Energy Act 2006, Section 27. A license or permit is required only if one intends to sell the power rather than use it for self-consumption or if the installation is larger than 1,000 kW. For this reason none of the flower farms audited is required to inform ERC or the utility Kenya Power (KPLC) about planned RE installations. However some of the farms have contacted the two organizations to establish whether net-metering could be put in place to compensate them in case their excess power is exported to the grid. The companies have installed a unidirectional meter that measures the output of the solar system. The public utility KPLC on the other hand possesses a meter that measures what the grid has supplied to the flower farm. At the time of writing, no provision for net-metering has been agreed.

4.2 Uhuru Flowers: 72 kW_p Solar PV

4.2.1 Description of the farm

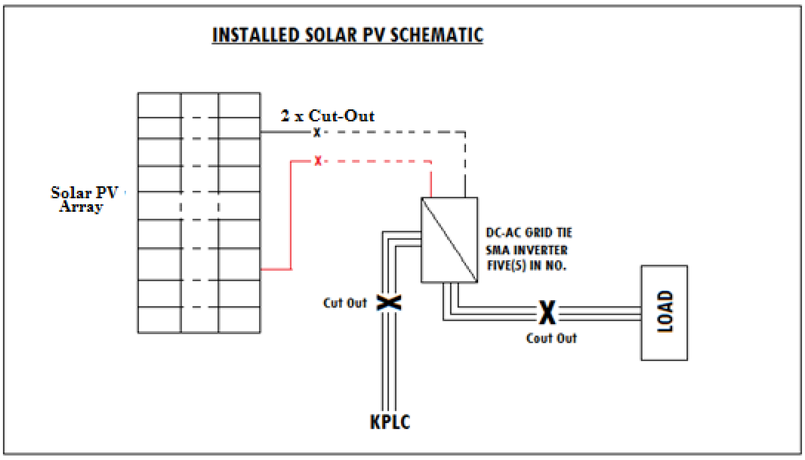
Figure 7: Roof-mounted PV installation & inverter installation at Uhuru Flowers

Uhuru flower farm is situated on the northern slopes of Mount Kenya near the town of Timau. The farm lies at an altitude of 2,600 m above sea level, making it one of the highest rose farms in Kenya. The high altitude combined with the latitude allows them to produce premium quality roses all year round. It was incorporated in Kenya in the year 1998. The latest development towards energy efficiency is the recent commissioning of a grid tied solar PV system of 72 kWp capacity installed together with five SMA Tripower Inverters. Each inverter has a capacity of 15 kW. With this installation 30 % savings in kWh consumption has been realized within the time.

4.2.2 Technical set-up of the solar PV system

The Uhuru solar plant is a grid tied system with five 15 kWp SMA inverter from Germany and roof mounted solar panels. There is also a standby diesel generator to provide a signal to the SMA Tripower Inverter whenever the grid fails. Since there is no battery backup, the solar AC power supplied by the SMA Tripower inverter is fed directly to the loads and the excess is supplied to the national grid via a single direction meter at the site. There are five arrays with 60 panels in each array. Each panel is 240 Wp at Standard Testing Conditions (STC).

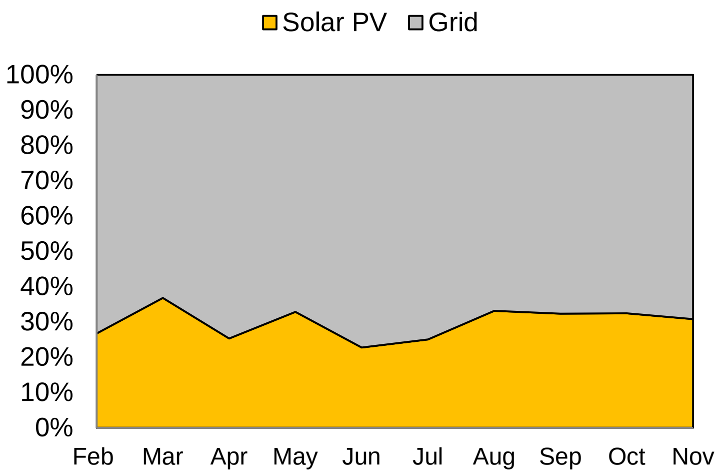
Figure 8: Schematic drawing of PV installation at Uhuru Flowers



Source: own graph

The figure below shows the output of the panels since February 2013 when the system was commissioned:

Figure 9: Monthly PV production data at Uhuru Flowers in kWh and grid replacement by PV since Feb 2013



2013	PV	Grid	Total
Feb	8,848	24,288	**33,136**
Mar	11,228	19,294	**30,522**
Apr	6,368	18,807	**25,175**
May	8,787	17,973	**26,760**
Jun	6,202	21,078	**27,280**
Jul	7,117	21,328	**28,445**
Aug	8,450	17,053	**25,503**
Sep	9,670	20,243	**29,913**
Oct	9,617	20,042	**29,659**
Nov	7,708	17,329	**25,037**

Source: own compilation based on data provided by Uhuru Flowers

Over this period the solar PV managed to displace about 30 % of grid power on average. A small portion of the solar production was exported to the grid without compensation from the grid operator. At the time of writing, Uhuru Flowers had not provided the author with the number of units that were exported into the grid but it is expected to be considerably low.

4.2.3 Cost Benefit Analysis

The solar PV system at Uhuru Flowers was commissioned in the month of February 2013 with an installed capacity of 72 kW_p. The costs for this particular solar system added up to about KSh 15 million (US$ 174,825) [9]. The 72 kW_p solar PV system has successfully displaced 30 % of the power requirements on average. This results an averaged energy saving of up to 8,399.5 kWh a month. By extension, this implies an annual figure of about 100,794 kWh of energy saved.

For a 100 % displacement of grid using net-metering the required size of the plant would be 202 kW_p and the plant would export 20,600 kWh (net) per annum initially. This figure would gradually decline with the degradation of solar panels and other parts or by growth in the size and energy demand of the flower farm. The farm's present annual power requirement is 337,716 kWh.

The average unit cost of electricity is KSh 18.00. The annual saving is projected at KSh 1,814,292 resulting in a simple payback period of about 8 years.

The payback period for this particular project could be improved by shifting the operational characteristics of the farm to ensure that most of the power is used by the equipment and that there is no excess exported to the grid at missing compensation. Our analysis showed that there will be an annual production of 127,968 units and of this about 27,000 units might be exported to the grid at no compensation. The payback will vary depending on how well this excess is distributed within the farm. We have assumed an average electricity unit price over 10 years which shall be 15 % higher than the current price. This gives an adjusted payback of only 6-7 years.

4.2.4 Ownership

This project is owned 100 % by Uhuru Flowers Ltd. They have taken out a 100 % loan which is not a non-recourse loan, using the balance sheet of the entire farm to secure it.

4.3 Tambuzi Ltd.: 60 kW_p Solar PV

4.3.1 Description of the farm

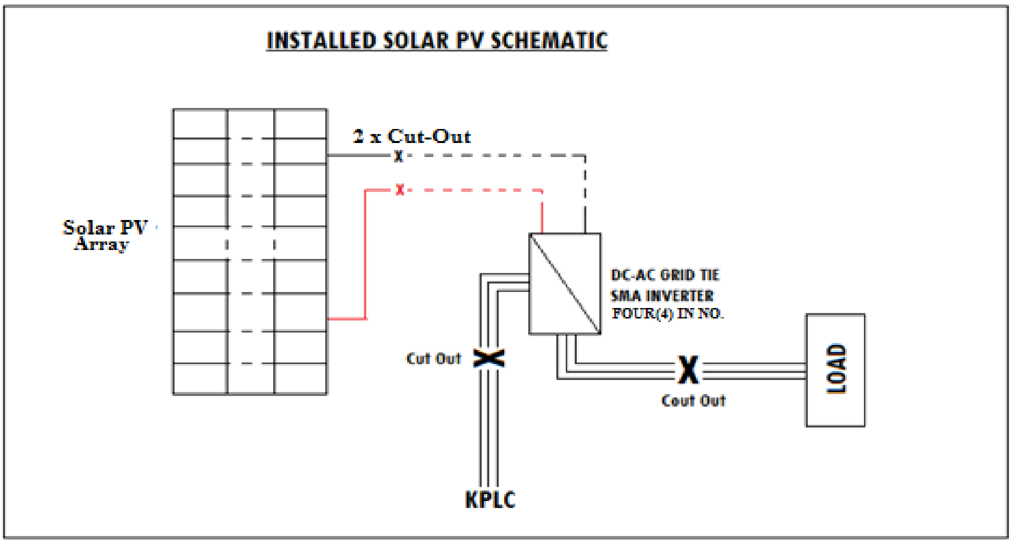
Tambuzi was founded in the mid-1990s and was originally a dairy and beef farm before incorporating flowers and vegetables in the production mix. Today it stands out as the only flower farm in Kenya with a specialty in producing and supplying traditional scented garden roses. Tambuzi Ltd. has a 64-hectare farm of which 25 hectares are currently used for horticultural production. The remaining 39 hectares are dedicated to sustainable forestry, bee keeping, vegetables and livestock.

4.3.2 Technical set-up of the solar PV system

The installed solar photovoltaic system capacity of Tambuzi Ltd. is about 60 kW_p. This comprises 240 panels of 250 W each and four SMA Tripower Inverters of 15 kW_p each.

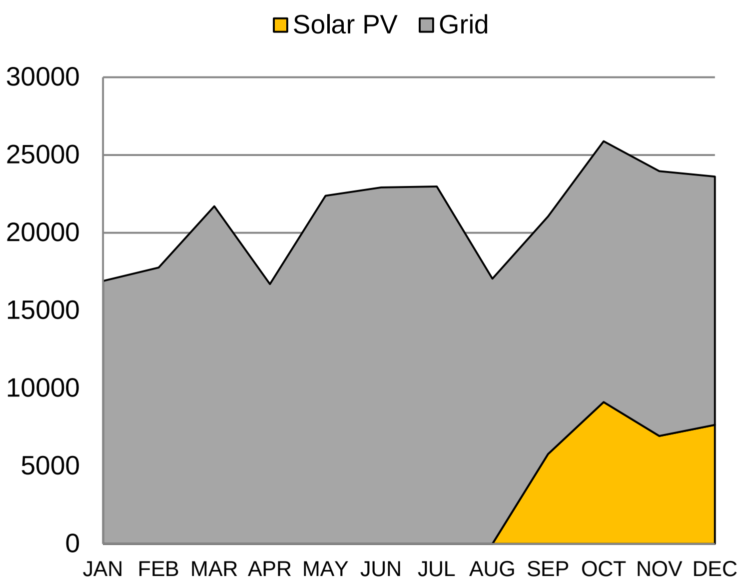
As shown in the figure below, the Tambuzi solar plant is a grid-tied system with four 15 kWp SMA inverters from Germany and several roof mounted solar panels. There is also a standby diesel generator to provide a signal to the SMA Tripower Inverter whenever the grid fails. Since there is no battery backup, the solar AC power supplied by the SMA Tripower inverter is fed directly to the loads and the excess is supplied to the national grid via a net meter installed at the site. The brain of the system is the multifunctional grid tie inverter.

Figure 10: Schematic drawing of PV installation at Tambuzi



Source: own graph

Figure 11: Tambuzi monthly grid consumption and solar production in kWh in 2013



2013	PV	Grid	Total
Jan	-	16,900	**16,900**
Feb	-	17,763	**17,763**
Mar	-	21,704	**21,704**
Apr	-	16,700	**16,700**
May	-	22,379	**22,379**
Jun	-	22,914	**22,914**
Jul	-	22,973	**22,973**
Aug	-	17,046	**17,046**
Sep	5,773	15,274	**21,047**
Oct	9,115	16,769	**25,884**
Nov	6,935	17,024	**23,959**
Dec	7,649	15,962	**23,611**
TOTAL	**29,472**	**223,408**	**252,880**

Source: own compilation based data provided by Tambuzi

4.3.3 Cost Benefit Analysis

Tambuzi solar PV system was commissioned in July 2013 with an installed capacity of 60 kW_p. The capital investment for the acquisition of the system is about KShs 12,000,000 (US$ 141,176) [10].

Table 11: Solar analysis and projections at Tambuzi

No.	Baseline Parameters	Value
1	Average energy consumption before installation of the solar PV system	**22,492.50 kWh**
2	Average energy consumption after installation of the solar PV system	**16,257.25 kWh**
Other Parameters for Analysis		
3	Average monthly energy savings with installation of the solar PV plant	**6,235.25 kWh**
4	Percentage savings (%)	**30%**
5	Monetary savings (monthly)	**KShs 130,940.25**
6	Monetary savings (annual)	**KShs 1,571,283.00**
7	Expected payback period (years)	**7.64**

Source: own compilation based data provided by Tambuzi Ltd

Based on the analysis the system has successfully supplied 30 % of the farm loading on daily basis, resulting in an average energy saving of up to 6,235.25 kWh a month. This gives an annual figure of about 74,823 kWh of energy saving. From this figure the annual monetary saving is projected at KShs 1,571,283.00 resulting in a simple payback period of about 8 years. This payback will vary depending on how the cost of electricity will evolve over the next 10 years. If it is assumed that the cost of electricity will average about 15 % over the current costs then the payback period decreases to 6-7 years.

4.3.4 Ownership

Tambuzi was 100 % debt financed by the Kenyan Bank Standard Chartered in Euros and at an interest rate of 5 % for a 5-year tenor. Standard Chartered granted Tambuzi a 12 million KSh loan (100 % of investment) [10]. The balance sheet of the farm was used to secure the loan.

4.4 Olij Roses: 100 % Independence from National Grid

Olij Roses is a rose breeder based in Naivasha. The Olij solar PV and solar thermal plant was launched in October 2013. It is named ‘Solar-Powered Greenhouse’ in Naivasha, Kenya. The project is a joint effort by Green Farming partners Van Zaal, hothouse builder Bosman, Hoogendoorn Growth Management and rose breeder Olij Roses, which collectively hope to strengthen and intensify horticultural business relationships across Kenya and Ethiopia.

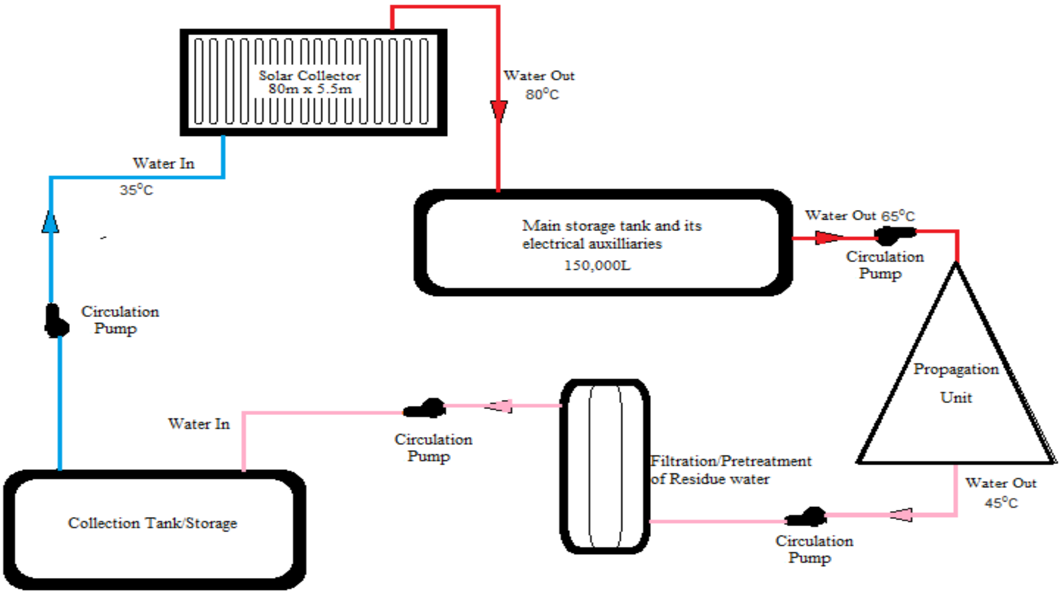
As energy costs in Kenya are continually rising, local flower farms are increasingly focusing on applying alternative energy sources. The “Solar-Powered Greenhouse” allows Olij to run its rose farm independently from the Kenyan electricity grid. By means of solar panels and solar heat collectors combined generation of heat and electricity is realised. This is used to heat the greenhouse at night and to provide the electricity needed to run the farm. Heating the greenhouse at night improves the quality of the roses. Excess heat and electricity are stored in a heat storage tank and battery pack. In case of too much generated electricity, it can be transformed into heat through an electrical boiler and stored.

4.4.1 Description of the Solar PV and Solar Thermal Plant

The Solar PV system comprises a 100.8 kW_p array of solar panels each panel being 240 W_p. It is a grid-tied system with a battery storage of 132 kAh (48 batteries of 2750 Ah) and 2 V each. There are seven 15 kW SMA Tripower Inverters based on 3-phase 50 Hz on-grid system. Additionally, six 10 kW Victron Charge Controllers store excess power in batteries and excess power supplies a 60 kW electric heater which is used to heat water. However, the main source of water heating is the solar thermal system, comprised of roof-mounted 180 m^2 solar collectors with a hot water storage of 150 m^3.

4.4.2 Technical set-up of the Solar Thermal Plant

Figure 12: Schematic of Solar Thermal Water Heating at Olij Roses



Source: own graph

4.4.3 Ownership

This is a joint effort project of three Dutch organizations with the aim of providing a pilot project for self-sustainability and being 100 % green by using only renewables.

4.5 PJ Dave Flowers: Biogas Plant

4.5.1 Description

Figure 13: Biogas plant at PJ Dave Flowers

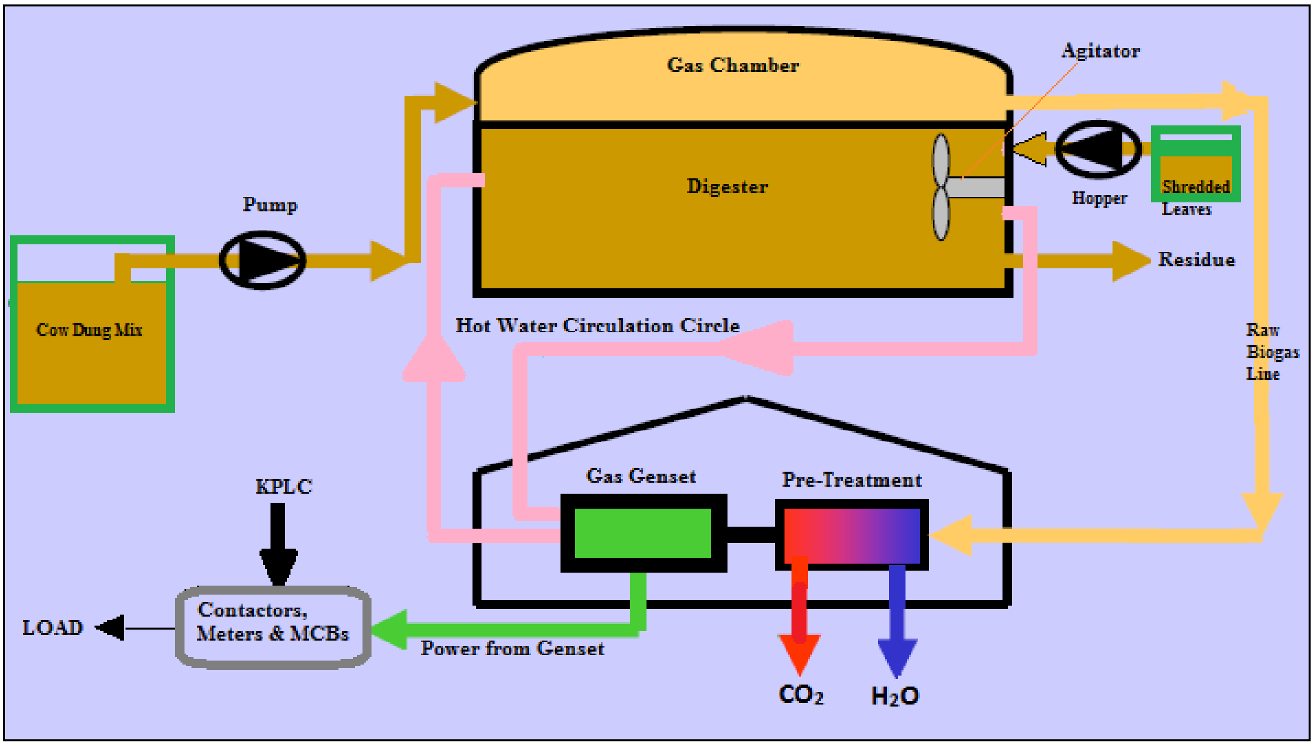
PJ Dave Flowers is located within the Athi Kapiti plains of Kenya, 60km south of Nairobi in Kajiado County along the Athi River–Kajiado–Namanga international highway and 1km south of Isinya District Headquarters. The PJ Dave Group initially started by growing vegetables such as French beans but diversified to roses in the year 1998. Since then the company made significant investments into modern greenhouses fitted with a computerized fertigation system, a pilot biogas generation plant fitted with a 125 kVA CAMDA gas engine generator as well as a reverse osmosis water filtration system for irrigation. The greenhouses currently cover over 85 hectares.

The PJ Dave Group manages four flower farms incorporated in Kenya as independent private limited liability companies. These companies are the PJ Dave Roses, PJ Dave Flora and PJ Dave Flowers Timau.

4.5.2 Technical set-up of the biogas system

The PJ Dave's biogas generation plant was successfully commissioned in the month of October 2013 and has been in operation for a period of two months at the time of the visit. The biogas technology used incorporates three systems: the biogas digester, the biogas pre-treatment plant and a three-phase biogas-fuelled generator for the conversion of biogas into electrical energy.

Figure 14: Technical system design and schematic process



Source: own graph

Cow dung and shredded flower waste form the major feedstock for the biogas plant which has a digester with a capacity of 400 m^3 and a gas chamber with a capacity of 167 m^3. The feeding is done once a day between 10.00 am and 3.00 pm. The farm then runs the gas engine for 2-3 hours to power 3 borehole pumps with a total rating capacity of 87 kW.

1) Waste production parameters:
   There are over three hundred cows within the farm producing of up to 500 kg of cow dung per day. The farm has a capacity to produce 5-6 tonnes of useful flower waste (leaves) per day but currently only half a tonne is used for the biogas production. There is still room for expansion of the bio-digester to produce more gas once the product moves beyond the pilot phase.

2) Feeding parameters:
   Cow dung of 400-500 kg mixed in a tank of 2 m^3 is fed-in on one side while half a tonne of shredded flower waste is fed through a hopper on the other side. The mixing of the slurry is done manually and its thickness is estimated by the operator.

3) Operation parameters:
   The entire system is operated manually (i.e. start and stop of the genset, manual power isolation and selection through a manual contactor switch). Hot water from the genset is circulated within the bio-digester to maintain required temperature for the bacteria when the genset is on. The existing internal temperature conditions are mapped through an installed thermostat.
   The 125 kVA gas generator runs for an average time of 2 hours a day. The genset serves three borehole pumps of capacities of 24 kW, 18 kW and 45 kW. At full gas bank (167 m^3) the generator operates for only 3 hours projecting a gas consumption of about 56 m^3 per hour. Since there is no gas meter installed in the system this is just estimation. Automatic shutdown is initiated whenever the gas is finished in the gas chamber.

4) Pre-treatment parameters of raw biogas:
   Gas from the digester is channelled through a pipe into the pre-treatment facility that removes and isolates water from the raw biogas. The biogas is then compressed to the required pressure to enable it to be used up in the gas engine.

5) Control data logging parameters:
   Within the system there are energy meters that record the power that is drawn by the three borehole pumps and the auxiliary units installed in the biogas plant. There are no gas flow meters to record the quantity of the raw gas generated and drawn up by the gas genset or pressure meters at the site that can act as a control for the entire system.

4.5.3 Cost Benefit Analysis

The project was built with the intention to demonstrate the technical viability. A cost benefit analysis would thus be misleading and is not done here. The project was a collaborative pilot project between MoEP and PJ Dave Flowers with a shared capital investment of 66.5 % (MoEP) and 33.5 % (PJ Dave) respectively. The overall capital for the project was KSh 19,000,000. The main contractor for the civil works was Pharma Engineers and was sourced by MoEP.

Table 12: The construction costs of the PJ Dave Biogas project

Item No.	Description	Cost (in KSh)	Cost (in US$)	% Contribution
1	Gas Engine, Accessories and Spares	4,447,304	51,118.44	23.3 %
2	Freight for Gas Engine and Spares	456,220	5,243.91	2.4 %
3	Electrical Works	907,998	10,436.76	4.8 %
4	Change over Switch	150,000	1,724.14	0.8 %
5	Other Installation Materials	78,570	903.10	0.4 %
6	Civil Works	12,700,000	145,977.01	66.5 %
7	Other Miscellaneous Costs	350,000	4,022.99	1.8 %
	Total	**19,090,092**	**219,426.34**	**100.0 %**

Source: own compilation based data provided by PJ Dave Flowers

The monthly operation and maintenance (O&M) cost is estimated to be KSh 10,500.00[3]. The O&M includes the salaries of three employees and minor maintenance and servicing of the system needed to successfully operate and run the system. However, replacement costs are not included. The 125 kVA CAMDA gas generator installed at the site only operates for a maximum of three hours when the gas chamber is full (at a capacity of 167 m^3). The gas generator was sourced from a manufacturer based in China. The unit serves three pumps with a total consumption of 87 kW. In a day, an estimated average of 174 kWh of energy is supplied by the genset.

4.5.4 Ownership

The plant is owned jointly by PJ Dave and the Ministry of Energy and Petroleum (MoEP) and was jointly financed.

4.6 Simbi Roses: Biogas Plant

Figure 15: Biogas plant at Simbi Roses

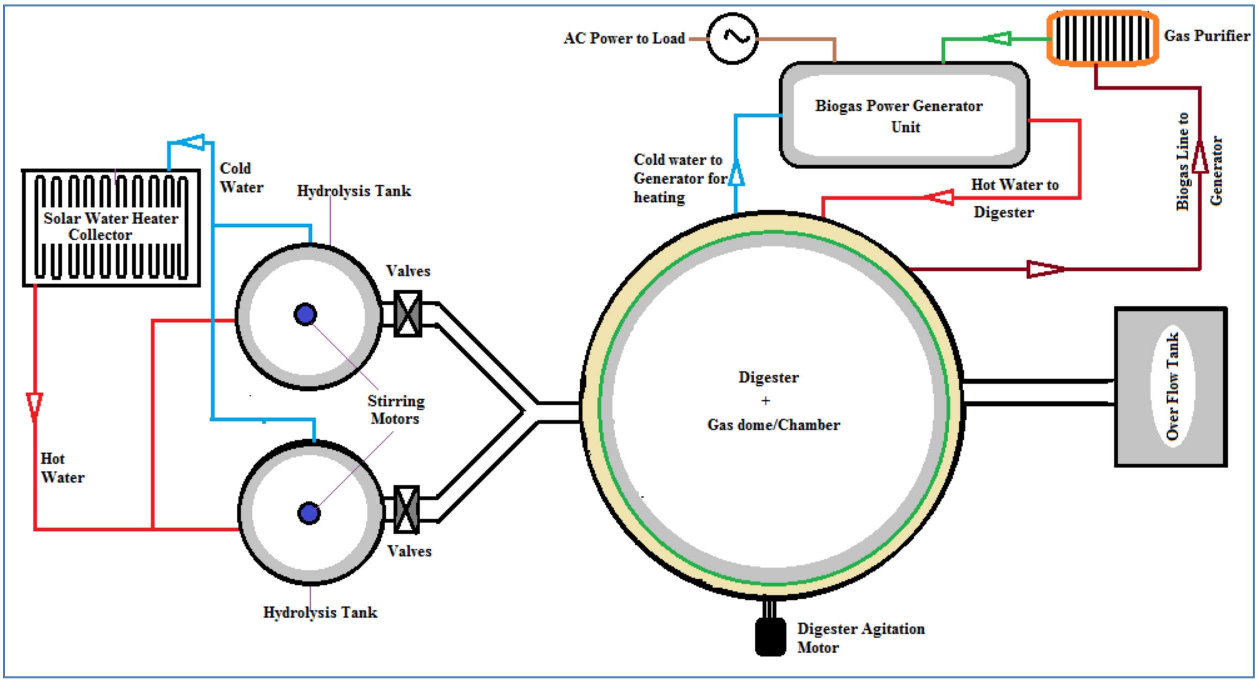
Simbi Rose farm is located in Thika, an hour's drive from capital city Nairobi. This proximity to Nairobi, the climate and constant water provision via several man-made dams in the area make the region popular for the agricultural industry. Simbi Roses farm itself is situated right in the centre of a large coffee farm. The farm was founded in the year 1995 with an original size of 2 hectares.

4.6.1 Description of the Biogas Plant

The process of feedstock generation from flower waste follows the same process as the one at PJ Dave described in the previous section. The biogas system at Simbi Roses uses only flower waste as feedstock while PJ Dave also uses cow dung.
The general layout of Simbi Roses' biogas system is as follows:

[3] According to PJ Dave management, the O&M costs for the two months running time have accounted for KSh 21,000.

Figure 16: Technical design and Process Schematic at Simbi Roses



Source: own graph

The system purely uses shredded flower waste and has a digester capacity of 200 m^3 and a gas chamber of 80m^3 capacity. The capacity of the biogas-fuelled generator is 55kW. It is a three phase system.

4.6.2 Technical set-up of the biogas system

1) <u>Hydrolysis tanks:</u>
Hydrolysis is splitting off a compound with water. This process differentiates the Simbi Roses Biogas plant from the one at PJ Dave where there are no hydrolysis tanks. All the feed stock is mixed in the biodigester. In Simbi Roses it is a solution with green matter that goes to the digester for biogas generation.

2) <u>Waste production parameters:</u>
The farm has a capacity to produce 2 tonnes of biodegradable waste from the cut flowers every day.

3) <u>Feeding parameters:</u>
On average, out of the two tonnes of daily farm flower waste, 600 kg of shredded cut flower leaves are fed into the hydrolysis tank. The shredded flower waste is mixed with water to dissolve the green matter which is then fed into the main digester. Mixing within the hydrolysis tank is done with the help of a 4 kW motor. The insoluble part of the flower waste which remains in the hydrolysis tanks is taken out once every two months.

4) <u>Operation parameters:</u>
The operation parameters of the system have to be strictly monitored to achieve high degree of gas production. The system is operated manually i.e. start and stop of the genset, manual power isolation and selection through a manual contactor switch. There is always a physical presence of staff to ensure system output optimization. The system is heated in two ways: First through an evacuated solar heating unit installed at the site to warm the content of the hydrolysis tank and second through waste heat recovery from the biogas engine generator to heat the content of the main biogas digester. There are various thermocouple meter installed for temperature monitoring.

The 55 kWp biogas generator runs 2-3 hours a day in average to supply power to the dam, fertigation and spraying pumps. This gives a total electric loading of about 36 kW when the load is connected to the genset. The generator is loaded only to a maximum of about 65 %. At full gas bank (80 m^3) the generator operates at 65 % loading for up to 4 hours projecting a gas consumption of about 20 m^3 per hour. At the time of the audit, the supplied energy by the generator set was 2,368.4 kWh with a recorded corresponding gas production capacity of 3,959 m^3. Thus 1.67 m^3 of gas produced from the biogas plant supplies 1 kWh of energy. Automatic shutdown is initiated whenever the gas chamber is empty.

5) Pre-treatment parameters**:**
Gas from the digester is channeled through a pipe into the pre-treatment facility that removes and isolates both water and CO_2 from the raw biogas. The biogas is then compressed to a required pressure for the gas engine.

6) Control data logging parameters:
Within this biogas system, there are both energy and gas meters installed for recording and monitoring purposes of the production data. Energy meters are recording the power that is drawn by the load installed within the biogas generation plant while the gas meter is recording the output gas amount that is fed into the generator whenever the system is operating.

4.6.3 Cost Benefit Analysis

The project was built with the intention to demonstrate the technical viability. A cost benefit analysis would thus be misleading and is not done here.
The installed 55 kW CAMDA gas generator operates for a maximum of four hours when the gas chamber is full (at a capacity of 80 m^3). The unit serves a load of 36 kWp during operation. The overall capital investment for the project was KSh. 15 million (US$ 176,470.00). The system has been in operation since May 2013 and since 8 months at the time of our visit.

4.6.4 Ownership

The plant is owned jointly by PJ Dave and the Ministry of Energy and Petroleum (MoEP) and was jointly financed.

5. Flower Farms with Potential for Renewable Energy Integration

The potential to develop solar PV systems exists in all flower farms. In fact, the latest observation is that the smaller farms are taking a leading position in adopting renewable energy solutions such as Uhuru flowers, Tambuzi, Olij Flowers, TimaFlors and Sangenta Pollen Ltd. All the farms with seedling propagation units also have potential to develop solar thermal units. These are Winchester, Isinya, Maasai and PJ Dave.

5.1 Integration of Solar PV

Based on the power consumption, the most interesting flower farms for the integration of solar PV were found to be the following:

Table 13: High potential candidates for solar PV integration

	Name of company	Location	Zone	Solar irradiation and other characteristics in the zone
1	Winchester Farm	Karen	Nairobi	DNI 5.79 kWh/m²/day
2	Isinya	Kajiado	Athi River and Kajiado	DNI 5.79 kWh/m²/day *(Dry zone; irrigation water is drawn from boreholes with high salinity)*
3	Maasai Flowers	Kitengela		
4	Harvest Flowers	Athi River		
5	PJ Dave[4]	Athi River		
6	Carzan Flowers	Rongai	Nakuru	DNI 5.76 kWh/m²/day
7	Red Lands Roses Ltd.	Ruiru (Kiambu)	Thika and Kiambu	DNI 5.97 kWh/m²/day in Kiambu, DNI 5.68 kWh/m²/day in Thika
8	Simbi Roses[5]	Thika		

Source: own compilation based on SWERA DNI NASA Low Resolution data

Uhuru Flowers and Tambuzi have already installed solar PV systems and will thus be taken as reference. The DNI is 6.51 kWh/m²/day and tilt radiation is 6.13 kWh/m²/day. The data from Uhuru Flowers showed that the actual grid displacement was about 30 % even though the solar installation generates power equivalent to 37.7 % grid displacement. The additional power produced is presently exported to the grid without compensation. Tambuzi indicated that they were consuming all the electricity generated by the solar plant, but the data had been collected for a short period of only 4 months. If indeed the farm consumed all the power produced by the solar plant it would amount to 40 % grid displacement.

[4] PJ Dave was not among the ones audited but was visited to review the existing biogas plant.
[5] Simbi Roses was not among the ones audited but was visited to review the existing biogas plant.

To determine the respective system size of a suitable solar PV plant, the following assumptions were made:

- Normalised panel rating: 240 W
- Panel Performance ratio: 78 %
- Overall system Performance Ratio: 70 %
- Cost per kW of normalised peak rating: US$ 2.300/kWp
- Targeted displacement of grid power: 30 %
- No Batteries included
- Debt interest: 5 %
- Portion of debt: 100 %
- Cost of electricity (US$ 0.207) increased by 15 % to account for average increase over 10 years

Based on these assumptions, the following estimates for the size of the solar PV plant can be achieved:

Table 14: Proposed solar PV sizes and investment requirement at the proposed sites

Flower Farm	**PV Size** (in kW_p)	**Space required** (in m^2)	**Investment** (in US$)	**Annual PV Production** (in kWh)	**Annual Consumption** (in kWh)	**Grid Displace-ment** (in %)	**Payback** (in years)
Uhuru Flower	**72**	545 m^2	**165,600**	127,319	337,716	37.7 %	6.28
Tambuzi	**60**	457 m^2	**138,000**	106,728	266,820	40.0 %	6.25
Winchester	**45**	343 m^2	**103,500**	77,083	256,944	30.0 %	6.49
Isinya	**279**	2119 m^2	**641,700**	475,931	1,586,436	30.0 %	6.51
Maasai	**158**	1196 m^2	**363,400**	268,596	895,320	30.0 %	6.54
Harvest Flowers	**218**	1656 m^2	**501,400**	372,036	1,240,120	30.0 %	6.51
PJ Dave	**734**	5566 m^2	**1,688,200**	1,250,169	4,167,230	30.0 %	6.52
Carzan	**303**	2294 m^2	**696,900**	504,879	1,682,929	30.0 %	6.67
Red Lands	**189**	1431 m^2	**434,700**	321,476	1,071,588	30.0 %	6.53
Simbi Roses	**116**	882 m^2	**266,800**	192,469	641,564	30.0 %	6.70

Source: own calculation based on data from various energy audits and above specified assumptions

The variation in payback from one farm to the other depends on the solar irradiation on-site. The higher the irradiation the shorter is the payback. For Uhuru Flowers the payback could be longer if they do not consume all the power they produce. If, for example, instead of displacing 37.7 % they only displaced 30 % the payback would be 7.9 years. Without net-metering it is critical to size the solar plant to exactly meet the energy needs without exporting anything to the grid. Load shifting to solar peak time is one way of increasing the utilization of excess solar power.

5.2 Integration of Solar Thermal

The farms which are suitable to install at least two renewable energy technologies to meet their energy consumption requirements are those that consist of both, flower farming and propagation units. The following farms include both categories: Winchester, Isinya, Maasai and PJ Dave Flowers.

Winchester is a very good candidate for solar thermal application since the kerosene and diesel cost for their hot water boiler was KSh. 15 million (US$ 172,500) per annum and therefore considerably higher than all the other flower farms. In none of the farms with propagations units, measurements of the temperature and flow rate of hot water in the propagation units were undertaken. Therefore it has not been possible to size the required solar thermal units needed to supply the propagation units.

Unfortunately, it was not possible to obtain information on the investment for the PV and solar thermal systems installed at Bilashaka or at Olij Flower farm in Naivasha. Both systems were already planned but not yet commissioned at the time of writing.

6. Conclusions and Recommendations

6.1 Commercial Viability of RE Projects at Kenyan Flower Farms

The application of solar PV technology is commercially viable and could provide a simple payback between 6-7 years depending on the assumptions of future electricity costs. This is possible while there is no battery storage and under the assumption that all power produced can be used 100 % internally. Currently, the installations aim to replace only 30 % of the on-grid electricity to avoid feeding electricity into the grid without any compensation since net-metering is not yet stipulated. Recent developments and public hearings on the issue show, that the passing of a net-metering regulation can be expected in 2015.
The application of biogas is still in the pilot phase and final conclusions as to the commercial viability of such projects cannot be drawn yet. A comprehensive project evaluation may be required before commercialization.

6.2 Financing Options for RE projects

All flower farms that were visited had either financed their RE projects through the assets of the farm together with regular loans or had fully financed them from their own cash flow without a loan. The loans were denominated in foreign currency either in Euros or US Dollars. This is a common practice for flower farms since they receive their revenue in forex. The companies that had taken out loans were subject to interest rates of around 5-7 % secured through the farm balance sheet. The loans exist for a time period of 10 years. This model can be extended to other flower farms since all flower farms are exporting their flowers and generating revenue in forex. Calculations indicated an average payback of 6.5 years assuming 30 % displacement of grid consumption and an average price of 15 % above the current price over the next 10 years.

6.3 Additional Work Required before Embarking on RE Projects

The energy audit reports are significantly missing information required for a significant evaluation of RE projects for various flower farms. No load curves and no assessment of renewable energy resource availability such as the amount of flower waste on each farm were provided in the reports. Where hot water is used for propagation, the reports provided no information on the water flow, water quantity and water temperature. This missing information is essential to enable an initial assessment of the farms' requirements in terms of renewable energy. Before designing and dimensioning RE systems on the farms, we recommend the initiation of detailed preliminary assessment and preparatory work on all the farms regarding their potential for RE

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