UPPSALA
UNIVERSITET

TVE 13 026
Examensarbete 15 hp
Juni 2013

Reducing costs and emissions at a cut flower plantation in Kenya

An assessment of electricity supply and transport

Felicia Bohm
Lovisa Ellegren
Linus Hansson

UPPSALA UNIVERSITET

Teknisk- naturvetenskaplig fakultet
UTH-enheten

Besöksadress:
Ångströmlaboratoriet
Lägerhyddsvägen 1
Hus 4, Plan 0

Postadress:
Box 536
751 21 Uppsala

Telefon:
018 – 471 30 03

Telefax:
018 – 471 30 00

Hemsida:
http://www.teknat.uu.se/student

Abstract

Reducing costs and emissions at a cut flower plantation in Kenya

Felicia Bohm, Lovisa Ellegren & Linus Hansson

Kenya is East Africa's strongest economy with good economic growth. The agricultural industry with horticultural products such as cut flowers plays an important part in the Kenyan export industry. However, Kenya faces serious infrastructure constraints in the power distribution sector that leads to frequent power interruptions. Backup power systems such as diesel generators are therefore often required. This report studies the possibilities to implement a solar power system to reduce the dependence on the national grid and a diesel generator, at a cut flower plantation in Kenya. Focus in the report is on costs and carbon dioxide emissions. The current electricity generation arrangement is compared with two alternative power solutions, one large-scale solar scenario and one small-scale solar scenario. The report also includes an assessment of cut flower transport from Kenya to Europe. Air freight and sea freight options are compared with consideration to costs and emissions. From data and calculations in this report the results show that a large-scale solar system implementation together with sea transport are the most beneficial solution.

Handledare: David Börjesson
Ämnesgranskare: Annica Nilsson
Examinator: Joakim Widén
ISSN: 1650-8319, UPTEC STS13 026

Table of contents

1. Introduction

Kenya is a country that over the years has been marked by problems like poverty and governmental turbulence. These problems still remain and the country is characterized by corruption with an estimated 45 % of the population living below the poverty line. Despite this, Kenya is facing a brighter future with good economical potential and a growth rate of 5-6 % over the last couple of years. Today Kenya is East Africa's biggest and strongest economy and the capital Nairobi forms the centrepiece of the expansive East African market (Regeringen, 2013). The agricultural industry is the largest export industry in Kenya, which makes it an important part of the Kenyan economy. Central in this industry are horticultural products and tea (Mekonnen et al., 2012).

A specific horticultural product that has become significantly important is cut flowers. The cut flower industry has developed rapidly over the last few decades and is now ranked as the third largest foreign exchange earner in Kenya. A bouquet of flowers bought at a supermarket in Europe may very likely been grown in Kenya, as about 25 % of the cut flowers in Europe come from Kenya (The Economist, 2008). The cut flowers are shipped from Kenya to Europe mostly by airplane. Most of the flowers are delivered to The Netherlands and then distributed to the European market (Ahlberg, 2007). In addition to the export potential the cut flower industry has created opportunities for jobs, income and infrastructure for the people in Kenya (Mekonnen et al., 2012).

A major part of the flower plantations in Kenya are located around Lake Naivasha. Lake Naivasha is a freshwater lake, meaning that the water from the lake can be used for irrigation at the plantation (Mekonnen et al., 2012). Water pumps and other electric appliances are powered by the national electricity distribution grid. However, the Kenyan electricity grid is prone to daily power outages and the plantations need diesel generators as backup systems (Ahlberg, 2007).

These power outages create incentives to look for alternative sources of power. This report investigates the possibility for a more sustainable and reliable energy supply with solar energy to cater for electricity needs at a Kenyan flower plantation. It is important that a potential solution is price competitive with both diesel fuel and electricity from the national grid. Furthermore the report involves a comparison between different power systems for the plantation and also investigating the most viable mode of transport of the flowers from Kenya to Europe, all of this with consideration to costs and greenhouse gas emissions.

This assessment was assigned by an organization called STUNS that promotes collaboration between the university, the private sector, and community in Uppsala. STUNS has a project called Power of Rays that aims to implement Swedish solar technology in Kenya. This report can be seen as a part of that project.

1.1 Aim

Considered in this report are the possibilities of implementing solar cells to produce power for a cut flower plantation in Kenya to get a reliable and environmentally friendly source of energy. More specifically, the aim of this study is to investigate the technical and economic potential of implementing solar cells to reduce the need for electricity from diesel generators and the national grid to power the electric appliances at a medium size flower plantation site in Naivasha. The report investigates costs and carbon dioxide equivalent emissions for the current power system, with the national grid and diesel generators as electricity supply, and alternative power systems that includes solar panels. The report also investigates the most viable mode of transport of the cut flowers from the plantation in Kenya to the distribution hub in The Netherlands and further on to Sweden.

In order to achieve this aim the report will attempt to answer the following questions:

- Is it feasible to implement a solar power system to produce electricity at a medium size flower plantation in Naivasha?
- With consideration to costs and emissions, what is the preferable type of power system and mode of transport?

1.2 Limitations

The focus in this report is on transport from plantation to customer and on the powering system, including the potential implementation of solar panels. Results from the feasibility study for implementing a solar power system will only be determined by quantified costs and carbon dioxide equivalent emissions. Both costs and emissions considered will be from transport and production and use of the electricity producing systems. No consideration is given to potential environmental impacts such as land degradation, overexploitation of water resources or use of agrochemicals. Furthermore, social impacts, such as health effects, poor labour practices and more, are not considered relevant for this study.

The calculations of the costs in this report are inevitable approximations since they are estimations for the next 25 years. The future prices for e.g. the electricity from the national grid in Kenya or diesel are predictions that are hard to make. Also, other economic uncertainties such as interest rates have not been taken into account in the calculations. Another aspect that is not included in the calculations for the cost of the solar power system is the expense from the installation of the solar system.

1.3 Outline

The following paragraph is an overview of the structure of the report. Two main sections runs parallel in the report, first a feasibility study of implementing a solar power system with focus on emissions and costs. Second, an investigation of two transport routes for the cut flowers from plantation to the final customer. In the background section necessary background information about the project is presented. This consists of information about the flower plantations in Kenya and the area around Lake Naivasha, fundamental information about solar energy and solar cells, electricity grid problems and different modes of transportation throughout the distribution chain. The methodology section includes descriptions about the methods, software and tools that are used to obtain necessary data. After the methodology section relevant data and calculations are presented. The data included in this section are emissions and costs from the power systems and the transport, amount of electricity used and produced and frequency of power outages. The next section in the report is a presentation of the results with a following discussion. Finally the conclusions are presented.

2. Background

This section includes relevant background information about this project.

2.1 Flower plantations in Naivasha

One of the main reasons for the rapid development of the cut flower industry in Kenya is the favourable natural advantage of suitable climatic conditions. With its location at the equator, Kenya has an ideal climate for all year round growing of flowers (Bolo, 2006). Kenya has two annual rainy seasons, from March to June and from September to October. The country has approximately 300 sunny days per year that means there is excellent solar radiation most of the time (Kenya Embassy, 2012). Lake Naivasha is located 80 km northwest of Nairobi. It is the second largest freshwater lake in Kenya and the land area around the lake is mainly used for cut flower farms and vegetable plantations. Current estimates suggest that there are more than 160 cut flower producers of different scale in Kenya. Lake Naivasha accounts for 70 % of Kenya's total flower exports and farms in the area rely on the lake for irrigation. Since it is a freshwater lake, water is obtained directly from the lake to the plantations (Mekonnen et al., 2012). This report will focus on a medium size plantation with 40 hectares of production of mostly roses.

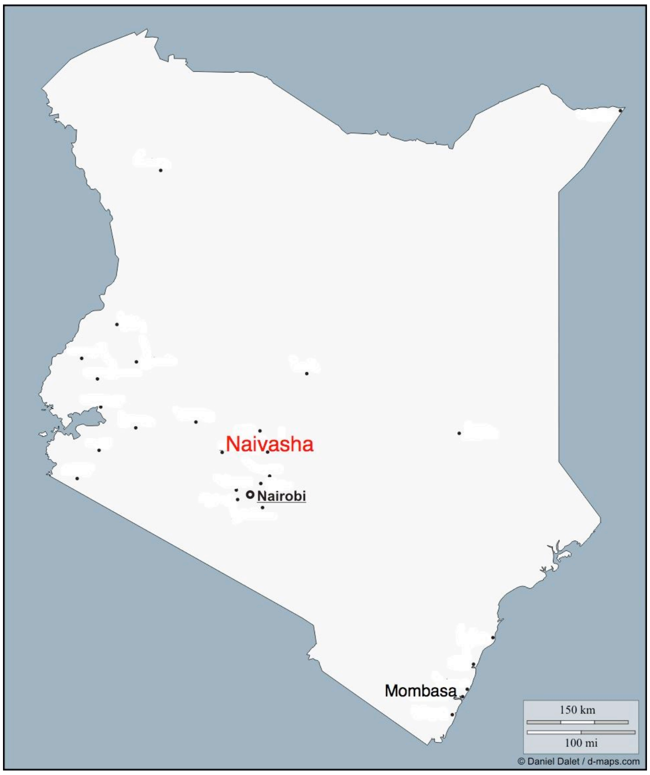

Figure 1. Map of Kenya

2.2 Electricity production and distribution

The electric appliances, such as water pumps, cooling systems, machinery and office at the plantation in Naivasha are powered by electricity from the national grid. However, a backup system is used because of frequent interruptions in power distribution due to electricity grid problems. Presently, a diesel generator is used as backup system to the grid. However, the combination of Kenya's location at the equator, with a lot of solar radiation and a limited number of rain days and an increasing cost of fossil fuel makes solar power an interesting potential alternative source for electricity.

2.2.1 Electricity grid problems

Kenya has considerable potential for economic growth because its economy is relatively diversified compared to other Sub-Saharan African countries. More than 50 % of the country's gross domestic product (GDP) comes from sectors, such as finance, tourism, information and communications technology, and trade, which are heavily dependent on reliable electricity supply. A main issue in Kenya is that the country faces serious infrastructure constraints, especially in the power sector with inadequate electricity supply and large geographical imbalance in power demand and supply. The level of electrification is low, particularly in rural areas, and less than 25 % of the total population is covered by the power generation capacity. The power sector infrastructure is a key element in the *Vision 2030* programme that aims to achieve increased economic growth and improve quality of life in Kenya (World Bank, 2011).

Even for the small percentage of the population that have access to electricity, the reliability is low because Kenya suffers from chronic electricity grid overload and shortfalls in energy supply. A lot of the outages are planned interruptions to reduce the pressure on the grid. The interruptions are usually at daytime and several hours long (KPLC, 2012).

Hydropower accounts for about half of Kenya's energy supply mix but the hydroelectricity output is negatively affected by inconsistent rainfall patterns, drought and destruction of water catchment areas. As a consequence of this scarcity of reliable electricity generation, the cost of doing business increases, which in turn weakens trade prospects and reduces competitiveness. It is estimated that these disruptions in power supply cost Kenyan firms about 7 % of their annual sales revenues. So this is clearly a constraint for reaching higher levels of economic growth. Also, as a consequence of a strong continuous population growth and urbanization a rapid increase in electricity demand is expected. The population in Kenya is growing, and it is estimated to continue to grow by one million people every year and, hence, almost double from 2010 to 2040 (World Bank, 2011).

2.2.2 Solar power

Solar energy is a renewable and environmentally friendly source of energy seeing that the only fuel needed is free and abundant solar radiation. Using solar cells, sunlight converts directly into electricity without any emissions. The amount of energy that can be produced in a solar cell depends on different parameters, such as the location where it is installed, the amount of sunlight and the temperature. The insolation on earth for one hour is enough to provide the global population with energy for a whole year (Energifakta, n.d.).

2.2.3 Solar cells

In order to produce electricity from the sun solar cells, also called photovoltaic cells (PV cells), are used. There are two types of PV cells, crystalline silicon cells and amorphous silicon cells. A silicon solar cell consists of a thin slice of a semiconductor material with contacts on both sides. When the PV cell is irradiated electrons are released from the silicon plate and start to move from positive to negative. The metal contacts pick up the charge in form of electric power. This continues as long as the sun shines on the cell and ends when the light disappears (Svensk Solenergi, n.d. a). The power from the cell is direct current (DC) therefore an inverter for converting the current into alternating current (AC) is required. The inverter also adjusts the voltage to the grid and is connected to the solar cell system and the electrical system. The life span of a cell depends on which type is being used and varies between 15-30 years (Svensk Solenergi, n.d. b). A silicon cell has a voltage of approximately 0.5 volts, which is too low to use as a single voltage source. Therefore several cells are connected in series to obtain an adequate voltage for the inverter. One solar panel consists of at least 36 solar cells (24 Volt, n.d.).

2.2.4 Solar power system

For an installation of a solar power system the number of panels required in the system have to be considered. To design the system, information about how the electrical demands varies, the variations of solar radiation, tilt angle and number of sunless days are needed. It is common with a battery connected to the solar system and to the electricity grid. The battery is charged by the solar panels and can then provide electricity during nighttime or on a cloudy day (Boyle, 2004, p.85). For the plantation in Naivasha no battery is required, instead the diesel generators or the electrical grid are used when there is not enough sunlight. To design the system, the amount of energy used in one day is calculated, and also the minimum hours of sunshine in one day. A solar cell can only convert about 10-15 % of the total insolation to electricity (Vattenfall, n.d.). There are also additional system losses in cables, inverters and more. These losses need to be considered when calculating the total number of panels in the system (Go-solar Systems Ltd, 2012). The cost to purchase and install solar panels varies a lot depending on the number of panels and the power output every panel must have. Compared to other electricity generating systems the environmental impacts from PV cells are low. There are no pollutants from gas or liquids and given that there are no moving parts there are no disturbing noises from the solar cells. The only carbon dioxide emission that comes from the solar cells is during the production process and gathering of raw materials. There can, however, be a visual impact on the surroundings if the PV cells are installed on the ground instead of on top of a building or facade. In the production of solar cells there is, in some panels, small amounts of toxic materials. However, the main material, silicon, is not essentially harmful (Boyle, 2004, p.95-96).

There are already a vast amount of solar electric systems installed in Kenya and an active market for solar equipment. Although at present, most of the PV systems in Kenya are off-grid solar home systems in areas out of reach for the power grid. A challenge for Kenya is the lack of technical capacity and competence in planning and installing of solar systems beyond the traditional market segments (Hille et al., 2011).

2.2.5 Swemodule

Swemodule is a Swedish company that produces solar panels and has a vision to be environmentally friendly. The company tries to optimize their resources to reduce the environmental impact and recycle as much of the materials as possible to prevent contamination. Their solar module is available in several varieties with different peak power between 210-260 Wp, and has a warranty for 25 years. Peak power (Wp) is defined as the output power that the solar panel produce under standard test conditions (Photovoltaic Software, 2012). Using new technology Swemodule is able to produce solar panels with relatively high efficiency. Swemodule claims that compared to standard PV panels their panels can increase the annual production with five percent. They are located in Glava in Sweden and have a worldwide distribution (Swemodule, n.d.).

2.2.6 Two future power system scenarios

In this project, two power system scenarios for future electricity generation at the flower plantation are studied. The first scenario is a large-scale implementation of solar panels to cover most of the electricity consumed during the day. On cloudy days the diesel generator and the national grid has to partially power the farm because the solar panels cannot supply enough electricity due to reduced irradiation. Hence solar panels are installed to cover most of the consumption rather than all of it. During the night the power source is the national grid. This scenario is referred to as “large scale solar” throughout the text.

The second scenario is a less extensive implementation. In this alternative the plantation’s base power supply is the national grid. However, the use of the diesel generator is decreased as much as possible. During power outages only the essential appliances are turned on. The irrigation pumps and cooling room always need to be in use and these account for approximately 24 % of total daytime electricity consumption at the farm. The solar power system in this alternative is calculated to cover these 24 %. The diesel generator is still necessary for power outages on cloudy days. This second alternative is referred to as “small scale solar” throughout the text.

2.3 Transport

In today's world a lot of industries are globalized, and so also the cut flower industry. The plantations are located far away from the main final markets, and the transport is without a doubt an essential part of the supply chain. Fresh cut flowers are time sensitive goods due to the fact that they are a perishable product, so it is of great importance that the transport is fast and efficient to ensure that the flowers reach their customers in time.

Time, temperature, and humidity are often seen as the most important parameters to preserve the flowers through the whole distribution chain. Cut flowers are sensitive to changes in temperature and need to be cooled down shortly after harvest. The plantation in Naivasha has cooling rooms where the cut flowers are stored directly after harvest. At low temperatures the ageing process is delayed, hence for most cut flowers a temperature of 4-8°C and 80 % humidity are preferred. Tropical flowers such as orchids require warmer temperatures. In a study by Svarén (2002), information about flower losses during distribution was obtained through interviews with actors involved in the process. According to these interviews, 5-20 % of the total losses were assumed as a direct consequence of incorrect temperatures. The importance of a stable and low temperature means that every disruption in the distribution flow, for example re-loading from one mode of transport to another, is a weak link and can have a negative effect on the quality of the flowers. If the transport is managed properly the cut flowers are minimally affected (Svarén, 2002).

2.3.1 Modes of transport

By far the largest proportion of flower exports from Kenya is supplied to Europe. Within Europe, The Netherlands is the main destination and from there flowers are rerouted to other European countries. The distribution chain for cut flowers from Kenya to The Netherlands includes several different modes of transport (Dolan et al., 2003).

The cut flowers from the plantation in Naivasha intended for the European market are typically transported by airplane from the airport in Nairobi to Schiphol, Amsterdam. For air transport it is uncommon to use refrigerated compartments, instead adequate temperature is reached when the plane has gained altitude (Svarén, 2002). Airplane is certainly the fastest mode of transport, it only takes a few days for the flowers to travel from plantation to the final customer. However, transport by plane is not all trouble-free. Airfreight is expensive and has the highest global warming potential of all modes of transport. It can generate 177 times more emissions than shipping (Soil Association, 2007). Also, the storage atmosphere with temperature and humidity is difficult to control and to maintain. Long flights may require a stopover for re-fuelling, which results in temperature fluctuations that can damage the cut flowers badly (Svarén, 2002). Furthermore, cut flower freight is often based on volume rather than weight. Consequently, producers tend to over pack boxes, which is detrimental to flower quality (Reid, 2009). The losses due to the flowers breaking when they are packed and transported by airplane are about 30 percent (Börjesson, 2013).

Transport of the flowers by boat is performed with refrigerated containers, commonly called reefer-containers, which provide a stable temperature. However, sea freight is slower. According to Hans Vonk, director at FTG Holland, it can take weeks for the flowers to reach the market and there are no direct shipping routes from Kenya to Europe (Vonk, 2013). A solution to this problem might come with new technology. The company FTG Holland has developed a new product for transport of flowers. The product as well as the company is called Flower Transport Gel (FTG) and it enables the flowers to stay fresh longer. The gel is water-based and contains nutrients and antibacterial agents to give the cut flowers the necessary moisture, nourishment and disinfection. The stem of the flower is put in a sealed plastic sleeve filled with gel. This creates a modified atmosphere, which increases the lifetime of the flowers. This makes it possible to transport the flowers by boat rather than airplane and, thus, reduce the costs for transport. Also, the gel enables the flowers to be transported horizontally, which facilitate packing of more flowers per volume compared to the traditional way of transporting flowers in buckets of water (FTG, n.d.).

In addition to the relatively slow transport, reloading can result in delays. During a shipping trial of cut flowers from Mombasa, Kenya to Rotterdam, The Netherlands the containers had to be transferred to another ship at Salalah Harbour in Oman. If the connection in Oman was missed due to delays, the container could not continue until 3 to 4 days later. Another problem with shipping is that there is an imbalance in reefer container transport. This means regular cargo might have to be transported in the more expensive reefer containers from Europe to Kenya to get sufficient containers in place for the cut flower export. The shipper of regular cargo does not want to be forced to pay a higher price for a reefer container that is not necessary. Therefore the extra charges have to be paid by the flower transport load to Europe. This considerably reduces the benefit of sea transport (Vonk, 2013). Another problem with sea transport is the unwillingness of shipping companies to release reefer-containers from the harbour for use on the continent (Cool Logistics, 2012).

From the plantation to the airport or harbour the flowers are transported by truck, preferably a reefer truck that can maintain the right temperature. The same goes for transport from the end port to the distribution hub in Aalsmeer, The Netherlands and onward to the European customers. For shorter distances at the end of the distribution chain regular trucks are commonly used and the cut flowers may even be transported together with other goods (Svarén, 2002).

3. Methodology

Several methods and software tools are used to obtain relevant information for this report. The following paragraphs presents each one of these.

3.1 PVgis

To calculate the potential electricity output from solar cells an online program called PVgis is used. PVgis is a program for calculating the solar energy produced by solar cells in a PV system in Europe or Africa. PVgis stands for photovoltaic geographical information system. An interactive map is presented in the program, where the geographical location of the PV system is selected. Geographic and climatic data and regional average values for irradiation are gathered from a database for the chosen location. To calculate how much electricity that can be generated, the type of PV technology has to be selected as well as several other parameters such as installed peak power, system losses and inclination and orientation of the modules. In this report polycrystalline silicon solar cells are investigated and the installed peak power depends on the exact model and quantity of modules used. Estimated system cause delivered power to the point of use to be lower than the actual produced power from the PV modules. These losses arise because of losses in cables, power inverters, dirt on the modules and more. The default value of 14 % is considered likely and is used in this report. Electricity output is calculated for freestanding PV modules rather than building integrated and a slope of 10 degrees is chosen. Even though Naivasha is located at the equator a slope of 10 degrees is preferred so that dirt can be washed off the modules by the rain. Azimuth is the angle of the modules relative to the direction due south, where east is -90 degrees and west is 90 degrees. The azimuth is optimized automatically in PVgis and results in an angle of between approximately -80 to -90 degrees for Naivasha to maximize the output. A tracking system is not implemented in the calculations, it is considered to be too expensive and require more maintenance. From its calculations, PVgis return values for average sum of global irradiation per square meter and average daily and monthly electricity production from the given system (Photovoltaic Software, 2012).

3.2 Life Cycle Assessment

A life cycle assessment (LCA) is a method used to analyse a product's, process's or service's environmental aspects and impacts. The approach in an LCA is to go through the whole lifecycle of a product from extraction of raw materials to production, manufacturing, transport, distribution and product use to the end of the product (EPA, 2012). To do this the typical structure is to work with four phases, namely, the raw material phase, the production phase, the operational phase, and the waste management phase. The outputs and inputs of all these phases are considered and the total environmental impacts are counted together as a result of the LCA (Solibro, 2010). The main goal of an LCA is to guide a producer of some type in the attempts to develop a more environmental friendly product, process or service. Often an LCA is used to compare two alternatives to see which one that would be preferable from an environmental perspective (EPA, 2012). A comparison of all phases in the product's lifecycle could be carried out, but there could also be a comparison of only one phase of the products.

This report includes a comparison between different powering systems for the flower plantation and also between two transport options for the cut flowers from Kenya to Europe. To compare these alternatives the unit kilogram carbon dioxide equivalents (kg CO_2e) is used. The power supply alternatives considered here are the electrical grid, a diesel generator and a PV system. These alternatives have more emissions in different phases of their life cycle and hence different phases are studied for each one of them. The diesel generator includes emissions in the production and operational phase during combustion, while emissions from the grid and PV systems mostly come from earlier phases such as raw material and production. The values for the total carbon dioxide emissions from the diesel generator and the national grid are calculated with emission conversion factors, which give an overall emission value for the powering systems. For the solar cells, results from previously made LCAs are used to evaluate the suitability of a PV system at the plantation in Kenya.

The comparison of the transportation from Kenya to Sweden includes three ways of transport, namely, airplane, boat, and truck. The transport of the flowers always has to go by truck from the plantation to the airport or the harbour, and the distances are different depending on the chosen alternative. Also when the flowers have arrived in The Netherlands they have to be transported by truck to Sweden regardless of if they came with boat or airplane. The LCA for the transport alternatives examines the operational phase, that is the actual transport, and not the raw material phase or the production phase.

3.3 EcoTransIT

EcoTransIT is a programme used to determine the environmental impacts and effects from different transports. The transport options available in the program are truck, train, airplane, and boat. Several parameters considering locations and type of freight are entered so that EcoTransIT can calculate the emissions. This is possible thanks to an extremely elaborated input method and a large amount of geographical information system (GIS) data. EcoTransIT use scientifically based data and the project has several independent partners who constantly provide the database with updates. The results provided by EcoTransIT are therefore considered reliable. Various institutions developed the program and their plan was to quantify the emissions from transport. There are many factors in freight transport that have an impact on the environment. All the elements that are necessary to operate a vehicle are included in the calculation of emissions. To get as close to reality as possible the type of loading site is specified, and also the weight of the freight. The results are compiled in a chart with the energy consumption and emissions of different contaminants from different transport modes (EcotransIT, n.d.).

In this report there are calculations for two different transport routes. One alternative is transport by truck from the plantation in Naivasha to the harbour in Mombasa, boat from Mombasa to Rotterdam and by truck from Rotterdam to Aalsmeer. Finally the flowers are transported from Aalsmeer to Stockholm by truck. The other alternative is to transport the flowers from the plantation to the airport in Nairobi by truck, from Nairobi to Schiphol in Amsterdam by airplane, and finally from Amsterdam to Aalsmeer and from Aalsmeer to Stockholm by truck.

3.4 GHG Protocol

Greenhouse Gas Protocol is a tool for accounting and managing emissions from different sectors and activities. In this report GHG Protocol is used to calculate indirect carbon dioxide emissions of purchased electricity from the national grid. The emissions are seen as indirect because they are emitted at the point of production rather than where the electricity is used. Emissions from electricity consumption from the power grid are based on an appropriate generic national average emission factor for the entire country. This factor is different for every country depending on the energy mix (GHG Protocol, 2007).

3.5 DEFRA 2012

Emissions from the diesel generator use are calculated with fixed conversion factors from DEFRA 2012 conversion tables. DEFRA 2012 is a similar tool as GHG Protocol. Global warming potential (GWP) factors are included for greenhouse gases other than carbon dioxide. Emissions can thus be presented in carbon dioxide equivalents. Both direct and indirect emissions can be calculated with DEFRA 2012 conversion factors. Direct greenhouse gas (GHG) emissions are emitted due to the use of the energy carrier, for example at the point of electricity generation in a diesel generator. Indirect GHG emissions are emitted prior to the use of the energy carrier. It considers emissions from extracting and transforming the primary energy source into the energy carrier, for example crude oil to diesel (DEFRA, 2012).

4. Data and Calculations

In the following section necessary data and calculations about electricity consumption, costs, and emissions are presented.

4.1 Electricity generation

The power interruptions on the national grid appear on average one out of twenty-four hours, usually at daytime (KPLC, 2012). Even if the interruptions usually are longer than one hour at a time but less frequent than every 24-hour period, the average value is used for calculations.

The farm has an electricity bill of 1.2 million Kenyan shilling (KES) per month and the price for electricity is 14.22 KES per kWh (Börjesson, 2013). The annual grid electricity use at the farm is thus 1 012 656 kWh per year.

It is assumed that the diesel generator is being used one hour every day, during the power outages, and that it runs at its rated capacity of 365 kVA (Power by Rays, 2013). In an AC generator the electricity output is seldom the same as the rated capacity measured in Volt-Ampere (VA). More commonly, the real output is 1/2-2/3 of this value and is measured in Watt. Assumed that the power output is 60 % of the rated capacity in kVA, which equals 220 kW, the electricity production from the generator is 80 300 kWh per year.

Total current electricity consumption for the plantation is thus estimated to be 1 092 956 kWh per year.

4.1.1 Cost for current power system

To run a diesel generator at a Kenyan plantation costs 35.6 KES per kWh (Börjesson, 2013). The total electricity cost for the plantation per month is calculated just by adding the cost for electricity generation from the diesel generator to the cost for electricity from the grid, which is 17 258 680 KES per year. This results in a cost of 15.8 KES per kWh.

4.1.2 Current distribution of electricity consumption

There are several assumptions considering the distribution of electricity consumption at the plantation. Most of the consumption occurs at daytime. The electricity use for the water pumps at the plantation is divided in two parts. The first part is lake water pumped up to a pond, this accounts for approximately 90 % of the pump work and can be adapted by the farm to whenever it suits them. The second is the irrigation of the plantation and this is done day and night to maintain the proper humidity and temperature. It is assumed that all pump work from the lake to the pond is done during the day when there is potential sunlight and electricity from solar cells can be used. Irrigation pumps are mostly used during the day because of evaporation in the greenhouses. 80 % of irrigation pump work is assumed to occur at daytime. The cooling room is constantly in use but due to higher outside temperatures at day, more energy is needed at that time. Approximately 70 % of the electricity to the cooling room is assumed to occur during the day. Offices, lighting and other minor applications are assumed to be used 80 % at daytime. Based on data of rated ampere for machinery and appliances together with these assumptions, it is estimated that 91 % of the total electricity consumption at the farm is from daytime activities (Börjesson, 2013). Multiplying this percentage with the total electricity consumption gives 994 590 kWh per year at daytime and consequently 98 366 kWh per year at nights. Furthermore Table 1 shows an estimation of the electricity use from each activity at the farm.

Table 1. Distribution of electricity consumption at the farm in Naivasha.

	Daytime use [%]	**Percentage of use during daytime**	**Daytime use** [kWh/year]	**Nighttime use** [%]	**Percentage of use during nighttime**	**Nighttime use** [kWh/year]
Water pumps	100	68.7	683 283	0	0	0
Irrigation pumps	80	14.8	147 199	20	38.7	38 068
Cooling room	70	9.6	95 481	30	43.2	42 494
Office, lighting etc.	80	6.9	68 627	20	18.1	17 804
Total		100	994 590		100	90 366

4.2 Implementing a solar power system

In PVgis, calculations are performed for the estimated solar electricity generated for one PV panel at a flower plantation in Naivasha. In Kenya the monthly variation in solar radiation is relatively small. Consequently, as Figure 1 shows, variation in electricity output from solar panels every month follow the same pattern. Therefore calculations are carried out with average yearly electricity production values. With a peak power value of 260 Wp PVgis returns an annual average value of 420 kWh per module, and for 210 Wp an annual average of 338.4 kWh per module.

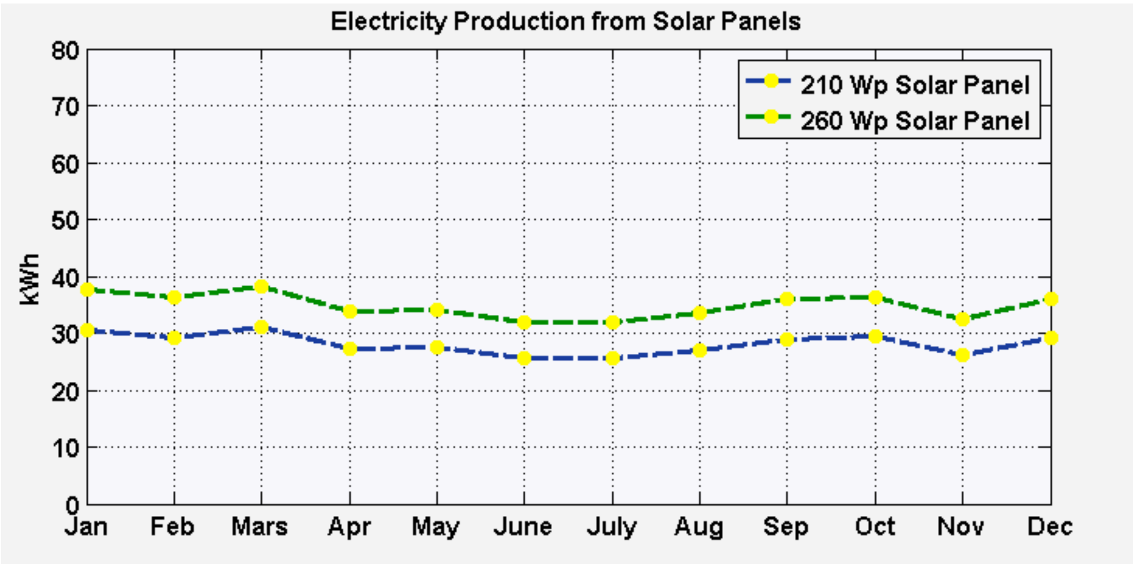

Figure 2. Average monthly electricity production from two different solar panels in Naivasha (PVgis, 2013).

For the large-scale solar scenario the panels are able to supply the total amount of daytime electricity used at the farm in a year. However, on cloudy days the power output from solar panels is reduced and thus not able to cover the demand during that time. Consequently on days with high irradiation the solar power output exceeds the demand. Because of this, there are estimations considering the level of use of the diesel generator and grid on the cloudy days. Calculations are based on the approximate data of Kenya having 300 sunny days, and hence 65 cloudy days. The solar panels cover an estimated 50 % of the demand on a cloudy day, so the diesel generator is calculated to be running at 50 % of its power capacity during power outages on those days. The diesel generator use sums up to approximately 7 150 kWh per year. Furthermore, when there is no power outage, the national grid is estimated to supply electricity to help cover the demand. The annual power output from the grid on the cloudy days is estimated to be 75 000 kWh. For the large scale solar scenario the total annual electricity consumption sums up to 1 175 106 kWh, which is 82 150 kWh more than the current power system at the farm. The number of PV panels required to generate the yearly daytime electricity of 994 590 kWh with a peak power value of 260 Wp is calculated by dividing the electricity daytime use with 420 kWh which gives a result of 2 368 number of PV panels. With a peak power value of 210 Wp the result would be 2 939 number of PV panels.

For the small scale solar scenario the solar power system supplies the plantation with 24 % of the daytime electricity consumption or 238 702 kWh per year. This means that most of the power supply at the farm still comes from the grid. Just as in the large-scale scenario, the diesel generator is in use during power outages on the cloudy days. The annual diesel generator consumption is estimated to 1 800 kWh and the power grid accounts for approximately 720 000 kWh of the total daytime electricity consumption. The total annual electricity consumption for the small-scale scenario is thus 1 058 868 kWh, a decrease of 34 088 kWh from the current power system. The decrease of electricity consumption in the small-scale solar scenario is due to the fact that some appliances are turned off during the power outages. For a solar power system to cover 24 % of total daytime consumption 568 number of PV panels with a peak power of 260 Wp are required. With a peak power value of 210 Wp the result would be 705 panels.

4.2.1 Cost for the solar system

Price index market data show that the price for a single solar panel in Europe today is approximately 0.8 € per Wp. Implementation of a solar system require however more components and additional costs than just the panels. This includes support structures, inverters, cables and other electronic components. To obtain the price for a whole solar system rather than just a panel, the panel price is multiplied by a factor of approximately 1.5-1.9 (pvXchange, 2013). Based on these data a price of 1.4 € per Wp, which equals 152.62 KES per Wp, is used for further calculations in this report.

To calculate the total price of each alternative the cost for one peak power value is multiplied with the total amount of Wp and the quantity of panels. The results are presented in Table 2 below.

Table 2. Total cost and required quantity of PV systems.

Large scale solar	**260 Wp**	**210 Wp**
Total cost [KES]	93 965 082	94 195 538
Quantity of PV panels	2 368	2 939
Small scale solar	**260 Wp**	**210 Wp**
Total cost [KES]	22 538 922	22 595 391
Quantity of PV panels	568	705

In both scenarios the 260 Wp system is cheaper than the 210 Wp system and requires less panels. The 210 Wp system needs a larger area and is more expensive for both alternatives so further calculations are performed only with a peak power value of 260 Wp.

Since the cost of installing the solar panels is a non-recurring expense, and the warranty time for panels from Swemodule is 25 years, the annual costs of solar power are calculated as a simplified levelized cost of electricity (LCOE) by allocating the total cost over 25 years. LCOE is defined as the constant price per unit of energy that causes the investment to just break even over a given period of time (NREL, n.d.). For the large-scale scenario this results in a cost of 3 758 603 KES per year. For the small scale scenario the cost is 901 557 KES per year. The calculated LCOE per kWh is 3.78 KES for both scenarios.

By comparing the plantation's current cost per kWh with the calculated cost of the potential solar power systems it is shown that the solar systems have a payback time of approximately six years.

4.3 Emissions from electricity generation

There are no continuous monitoring and recording of emissions at the plantation so the amount of emissions is obtained by using data for electricity consumption and adding relevant conversion factors.

4.3.1 Emissions from the national grid

Emissions from electricity generation by the Kenyan national grid are calculated using GHG Protocol values for 2009. The emissions are calculated in kg CO_2 per kWh produced. For Kenya a total factor of 0.395 (World Resources Institute, 2012) is multiplied with the amount of electricity consumed to get the related emissions. By multiplying the total grid electricity use for the plantation, 1 012 656 kWh per year, with the conversion factor, the current carbon dioxide emissions are calculated as 399 944 kg CO_2 per year.

In the large scale solar scenario the national grid supplies the plantation with electricity during the night and on the cloudy days to complement the PV panels. The electricity required during the night is 9 % of the total electricity consumption and together with the consumption during the cloudy days the total electricity consumption from the national grid per year would be 173 366 kWh. The carbon emissions from the national grid in this scenario are 68 470 kg CO_2 per year. In the small scale scenario the national grid supplies the plantation with 818 366 kWh per year and the carbon dioxide emissions are 323 210 kg CO_2 per year.

4.3.2 Emissions from solar cells

Hsu et al. (2012) formulate a median value of 45 g CO_2e per kWh produced is GHG emissions from a solar cells lifecycle (Hsu et al., 2012). In the large scale scenario the solar power system has to produce 994 590 kWh per year and by multiplying that with the carbon dioxide equivalent for solar cells the GHG emissions from a plantation is calculated to 44 757 kg CO_2e per year.

For the small scale scenario the amount of electricity that the solar panels produce is 238 702 kWh per year and the GHG emissions from a plantation are calculated to 10 742 kg CO_2e per year.

4.3.3 Emissions from diesel generator

The fuel consumption for the diesel generator is estimated to 0.3 litres per kWh. It is assumed that the generator runs at 220 kW during power outages one hour every day, 365 days per year. The total annual diesel usage can, thus, be calculated as the product of the fuel consumption for 365 hours and the power for the diesel generator which gives 24 090 litres per year.

Using DEFRA 2012 conversion tables, values for emissions are calculated. For diesel fuel consumption, fixed conversion factors are used for three different types of emissions, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Carbon dioxide accounts for the majority of the GHG emissions from most stationary combustion units such as diesel generators. Different conversion factors are used to calculate direct and indirect GHG emissions. Including both direct and indirect GHG emissions gives the conversion factors shown in Table 3.

Table 3. Conversion factors for direct, indirect and total emissions from diesel fuel (DEFRA, 2012).

GHG-type [kg CO_2 per litre]	**CO_2**	**CH4**	**N_2O**	**Total direct GHG**	**Total indirect GHG**	**Total GHG**
Conversion Factor	2.6569	0.0009	0.0191	2.6769	0.5644	3.2413

By multiplying the conversion factor for the total GHG with the amount of diesel used, in litres per year, the total GHG emissions for the diesel generator in kg CO_2e are calculated. With a diesel consumption of 24 090 litres per year, the total GHG emissions are 78 083 kg CO_2e per year. Direct emissions account for 64 487 kg CO_2e per year while indirect emissions account for 13 596 kg CO_2e per year.

In the large scale solar scenario the annual diesel usage for the generator is 2 145 litres per year which leads to a total GHG emission mass of 6 953 kg CO_2 per year. In the small scale solar scenario the generator consumes 540 litres per year giving a total emission mass of 1 750 kg CO_2 per year.

4.4 Emissions from transport

One single forty foot freight container can hold 297 000 roses. A plantation of 40 hectares produces 23 million roses per year, which equals 78 containers per year, or 6.5 containers per month. The annual transport weight of cut flowers is 772.2 tonnes, this means that one container weighs 9.9 tonnes fully loaded (Börjesson, 2013). For calculations in EcoTransIT the single container weight of 9.9 tonnes is used and then multiplied by the number of containers per year to get the annual emissions value.

Two different transport route options are considered, which include different modes of transport. The first option, "Air", includes airplane as the main mode of transport while the second option, "Boat", mainly considers transport by boat. Both the Air and the Boat option include truck transport to and from the harbour and the airport and from Aalsmeer to Stockholm. The two routes and their related emissions can be seen in Table 4 and Table 5. An important parameter included in the calculations for air freight is the so called RFI-factor, it means that consideration is given to the fact that emissions emitted in higher atmospheric layers have a greater impact than emissions on ground level.

Table 4. Emissions from transport, from Naivasha, Kenya to Stockholm, Sweden, with Air.

Origin	**Destination**	**Distance** [km]	**Mode of Transport**	**Emissions per trip** [tonnes CO_2e]	**Annual Emissions** [tonnes CO_2e]
Naivasha	Jomo Kenyatta International Airport, Nairobi	108	Truck	0.073	5.70
Jomo Kenyatta International Airport, Nairobi	Schiphol, Amsterdam	6 997	Airplane	129.00	10 062.00
Schiphol, Amsterdam	Aalsmeer	9	Truck	0.0054	0.42
Aalsmeer	Stockholm	1452	Truck	1.08	84.24
Total		**8566**		**130.16**	**10 152.36**

Table 5. Emissions from transport, from Naivasha, Kenya to Stockholm, Sweden, with Boat.

Origin	**Destination**	**Distance [km]**	**Mode of Transport**	**Emissions per trip** [tonnes CO_2e]	**Annual Emissions** [tonnes CO_2e]
Naivasha	Mombasa Harbour	577	Truck	0.42	32.76
Mombasa Harbour	Rotterdam Harbour	11 673	Sea Ship	0.84	65.52
Rotterdam Harbour	Aalsmeer	71	Truck	0.041	3.20
Aalsmeer	Stockholm	1452	Truck	1.08	84.24
Total		**13 773**		**2.38**	**185.72**

4.5 Costs from Transport

In the following section the costs for each mode of transport within the route options are presented.

4.5.1 Costs from air freight

Today's airfreight price for high season is 151.22 KES per kilogram and during mid and low season the kilogram price is 95.90 KES. The average price is 123.56 KES per kg for a full year. The annual weight of the exported flowers is 772 200 kg (Vonk, 2013), which by multiplying with the average price per kilogram results in an air freight cost of approximately 95 413 032 KES per year.

4.5.2 Costs from truck

There are two different routes with the truck depending on if the other choice of transport is airplane or boat. Due to the choice of transport it will differ in distance for the truck and that will affect the costs. The calculations for the truck costs are based on a truck that runs on diesel and consumes 0.45 litres per km. The diesel cost for Kenya is 97.41 KES per litre, for The Netherlands 173.09 KES per litre and for Sweden 163.10 KES per litre (Se.gas-globe, 2013). With the fuel consumption for the truck, the diesel costs, and the distance for the truck to drive in each country, the cost for each distance are calculated. To get the annual costs the results are multiplied with the number of transportations in one year, i.e. 78 transportations. The distances are calculated using Google Maps and the resulting cost for the transport option Air is shown in Table 6 and the cost for the transport option Boat is shown in Table 7.

Table 6. Costs from truck transport for option "Air".

Origin	**Destination**	**Distance** [km]	**Cost** [KES per year]
Naivasha	Jomo Kenyatta International Airport, Nairobi	108	369 272
Schiphol, Amsterdam	Aalsmeer	9	54 070
Aalsmeer	Stockholm	1452	8 312 342
Total		**1569**	**8 735 684**

Table 7. Costs from truck transport for option "Boat".

Origin	**Destination**	**Distance** [km]	**Cost** [KES per year]
Naivasha	Mombasa Harbour	577	1 972 816
Rotterdam Harbour	Aalsmeer	71	431 358
Aalsmeer	Stockholm	1452	8 312 424
Total		**2100**	**10 716 598**

4.5.3 Costs from sea freight

According to the company FTG Holland, who have done a price comparison of air and sea transport, the cost for sea freight varies but it is nowadays considered to be no less than 80 % of the total air freight price. The costs of sea freight have increased because of higher shipping rates, taxes and fuel price (Vonk, 2013). In early 2013, Maersk Line increased their reefer base rates with US$ 1 500, which in turn increase the costs for sea transport of perishables such as cut flowers (Maersk Line, 2012). H. Vonk states that there are also often unexpected costs with trucking to Mombasa, and the handling and customs procedures at the harbour (Vonk, 2013). To calculate the minimum price for sea freight the truck price for the option "Boat" is subtracted from 80 % of the total price in Air. The cost for sea freight is thus calculated to 72 602 376 KES per year.

5. Results

In following section the results from data and calculations are presented.

5.1 The total emissions

The total emissions from the plantation as a result of to the electricity production and the transport of the flowers is at present approximately 10 630 027 kg CO_2e per year. However, currently, the transport from Kenya to The Netherlands is by truck and air freight. If the air freight is replaced by sea freight the total amount of carbon dioxide emissions would be reduced significantly to 664 027 kg CO_2e per year.

Table 8. The total GHG emissions from the various options.

	Currently [kg CO_2e]	**Currently + Boat** [kg CO_2e]	**Large scale solar + Air** [kg CO_2e]	**Large scale solar + Boat** [kg CO_2e]	**Small scale solar + Air** [kg CO_2e]	**Small scale solar + Boat** [kg CO_2e]
National grid	399 944	399 944	68 470	68 470	323 210	323 210
Diesel generator	78 083	78 083	6 953	6 953	1 750	1 750
PV panels			44 757	44 757	10 742	10 742
Air	10 152 000		10 152 000		10 152 000	
Boat		186 000		186 000		186 000
Total	**10 630 027**	**664 027**	**10 272 180**	**306 180**	**10 487 702**	**521 702**

The result of the large-scale solar scenario combined with sea freight is a total emission value of 306 180 kg CO_2e per year. Compared to the current amount of emissions at 10 630 027 kg CO_2e per year this combined scenario would make the greatest reduction of carbon dioxide emissions of all the options presented. This scenario has an emission mass of approximately only two percent of the current arrangement. An interesting observation is that the solar panels in this scenario account for less emissions than the diesel generator in the current solution even if the diesel generator is only operating one hour a day.

The system that emits by far the most carbon dioxide emissions in the suggestions given in Table 8 is air freight with approximately 10 152 000 kg CO_2e per year. For the transport, the difference in emission mass between airfreight and sea freight is remarkable. The Air option emits more than 50 times as many kilograms of carbon dioxide equivalents than the Boat option.

5.2 The total costs

When it comes to costs, there are also notable differences between airfreight and sea freight. A major incentive for using sea freight instead of airfreight is the difference in price. With the calculated costs seen in Table 9, Boat turns out to be almost 21 million KES (1 459 500 SEK) cheaper per year than Air. The most expensive part of the distribution chain is without a doubt the air transport from Nairobi to Amsterdam. With a price tag of 95 413 032 KES (6 631 206 SEK) per year it accounts for 92% of the total costs for Air.

Table 9. The total costs for the various options for transport and electricity generation.

	Air [KES/year]	**Boat** [KES/year]	**Current electricity gen.** [KES/year]	**Large scale solar** [KES/year]	**Small scale solar** [KES/year]
Airfreight	95 413 032				
Sea freight		72 602 416			
Truck	8 735 684	10 716 557			
National grid			14 399 968	2 465 265	11 637 165
Diesel generator			2 858 712	254 240	64 080
Solar panels				3 758 603	901 557
Total	**104 148 716**	**83 318 973**	**17 258 680**	**6 478 408**	**12 602 802**

With sea freight, more truck transport is required than with air freight because the harbour in Mombasa is further away from Naivasha than the airport in Nairobi. This leads to a higher truck transport price for Boat. However, the costs from truck transport are relatively small in view of the total distribution chain. Also to be mentioned, the cost per kilometre is fairly similar for both sea and truck transport while air transport is significantly more expensive.

The different choices of power supplies for the flower plantation compared in this report are the national grid, the diesel generator and solar panels. By comparing the price per kWh for the various forms of electricity generation, it becomes evident that a solar power system is the best option.

- National grid: 14.22 KES per kWh
- Diesel generator: 35.6 KES per kWh
- Solar panels: 3.78 KES per kWh

The proportions of the different types of electricity generation in the current solution and for the two scenarios are presented in Table 10. With the current electricity supply solution, the national grid stands for most of the electricity supply at a share of 93 %. The diesel generator is only operating during the power outages and stands for 7 % of the total electricity generation. The total cost for today's electricity supply is 17 258 680 KES (1 199 478 SEK) per year.

With the large-scale scenario, solar panels are used as much as possible during daytime, and they cover 84.6 % of the total electricity consumption. The national grid and the diesel generator stand for the rest of the share. This scenario would mean a total annual cost of approximately 6.5 million KES per year. Compared to the current annual electricity cost it is a cost reduction of approximately 10.8 million KES or 760 000 SEK per year.

In the small scale solar scenario the national grid is the main power supply with 77.3 % of the total use. Solar panels are only used to provide the essential parts of the farm and stands for about a fifth of the electricity generation. The total cost for this alternative is about 12.6 million KES per year. The savings in this case is 4.7 million KES or 330 000 SEK per year.

Table 10. Proportions of the various options for electricity generation.

Electricity supply	Distribution grid	Diesel generator	Solar panels
Current	93.0 %	7.0 %	0.0 %
Large scale solar	14.8 %	0.6 %	84.6 %
Small scale solar	77.3 %	0.2 %	22.5 %

6. Discussion

Due to the limited specific data that could be obtained from the plantation and its operations many assumptions have been necessary throughout this report. General data have been the basis for several of these assumptions so the report can give an overview of how a future power system and distribution chain can work. Consequently exact numbers in data and calculations and in the end result are to some extent assumptions and estimations and are not a definite result for the plantation in Naivasha. However, from data and results it is still possible to derive necessary conclusions.

On the topic of transport and regarding the two parameters studied in this report, costs and emissions, the best option for the farm is to ship the flowers by boat. The positive outcomes from shipping the cut flowers by boat is both lower costs and significantly reduced GHG emissions compared to air freight. Transport is the main contributor to emissions, and airfreight is especially bad.

There are however other important factors to consider when investigating the suitability of the different modes of transport. Because of the time and temperature sensitive nature of cut flowers, consideration must be given to the ability to control these parameters throughout the distribution chain. An issue with sea freight of perishable products such as cut flowers is the fact that it is a relatively slow mode of transport. Even with new innovations such as Flower Transport Gel to overcome this obstacle, sea transport from Mombasa to Rotterdam faces problems with risk of delays that can reduce the quality of the flowers. It is important to have a time reliable distribution to maintain high quality flowers but also to ensure that the cut flowers reaches the market at the right time. It is uncertain if one of the two modes of transport, sea freight or airfreight, can ensure higher quality flowers to the final customer than the other. Temperature is more easily controlled with sea freight and the flowers can be packed in a way that makes them less vulnerable. If reefer containers can be loaded at the plantation and transported in the same container all the way to Aalsmeer the right temperature is maintained and the cool chain is not broken, which means the cut flowers are minimally affected throughout the whole distribution chain. For airfreight it is necessary to reload the flowers at several occasions and hence expose them to temperature changes that can reduce their quality. More trial shipments might be required to be able to conclude the feasibility of sea freight. If flower quality can be maintained sea freight can lead to considerable emission reductions.

When considering both emissions and economics for the power system scenarios, the large-scale solar scenario with a solar power system to cover up as much of the daily electricity demand as possible, is most favourable. The financial aspect is crucial to decide if a new power system is to be implemented or not, and since this scenario has the lowest annual cost of the different alternatives, it is the preferred one. However, there are aspects not included in the calculated costs for implementing solar panels.

The annual values that are presented for implementing the solar power system are divided over 25 years. Some additional costs besides the implementation of the solar power system are probable. Costs that are not included in calculations in this report are the potential shipment of the solar system from where it is produced to Kenya. Also, costs for installation of the system have not been accounted for. So there will be larger costs than the results in this report shows and especially considering implementation of the solar system. However, relative to the major costs of the cut flower transport and purchase of the solar power system, additional costs are assumed to contribute only with a minor cost increase. Even if the costs are divided over a longer period of time, the actual purchase is a one-time expense, which means there is a major initial investment that the plantation has to cover to be able to implement a new power system. The practical measures required to manage that expense is not included in this report but might be a limiting factor to the feasible extent of a solar system implementation.

Another problem with the implementation of the solar panels is that they require a special expertise. Kenya has a lot of competence in PV technology and implementation for off-grid solutions. The solar system installation presented in this project is an on-grid solution and requires certain competence that might not be as readily available. If the installation of solar panels in the large-scale scenario is executed it will lead to a major installation of almost 2 400 panels, which will require a large area. Logistic solutions to where these panels should be placed will also be necessary. Theoretically, it is most advantageous to implement as many solar panels as possible to cover for the plantation's power demand. In practice, it may not be possible to install such a large system. The small-scale solar scenario is a less extensive installation, with about 570 panels, so if the area is a problem this option could be a good investment too.

In this report it has not been taken into account that the efficiency of the solar panels may decrease over the years. This means that the farm might require more electricity from the national grid and from the diesel generator than estimated. Also, the price for electricity from the grid and the price for diesel are presumably going to change during the years, so this makes it difficult to calculate a precise cost for the electricity. If the farm needs a loan to manage the costs for solar panels there would be a certain interest rate, and that is not included in this report.

The flower plantation in Naivasha could save a lot of money and reduce emissions over the years if they did invest in a solar power system. There would probably be challenges in the beginning, for example to find the right expertise and to cover the initial expenses, but if they could manage the implementation, a solar system would be a good idea. The prospects for a future of solar power at the plantation are promising, since Kenya has very suitable climatic conditions and the costs for PV technology are decreasing.

7. Conclusions

It is feasible to implement a solar power system to a plantation in Kenya. Although a large financial investment for the plantation is required. In this report two future power system scenarios were studied. A large-scale solar scenario where solar panels are used as much as possible during daytime and the national grid and diesel generator during night and on the cloudy days. In the small-scale solar scenario the national grid remains to be the base power supply and the use of the diesel generator is minimized as much as possible. When there is a power outage the solar panels provide only the essential appliances with electricity. The most preferable type of power system is the large-scale scenario, seen over 25 years it is the least expensive option and has the smallest amount of emissions. There are however financial aspects that have not been included in the report so some uncertainties remain. Regarding the modes of transport sea freight is the most beneficial option in terms of emissions and costs. Changing from airfreight to sea freight would mean a considerable reduction of emissions. The quality of the cut flowers are however affected by other factors such as time and temperature that has to be considered.

8. References

24 Volt. *Solpanel*. Available online: http://24volt.eu/solcell.php (2013-05-15)

Ahlberg, S. (2007), *Rättvisemärkning av snittblommor på den Svenska marknaden*, Examensarbete, SLU, Institutionen för växtvetenskap.

Andreasson, K., Edman, J., Hedberg, P. (2010). *Q-Cells SL1-75: Energianalys av en CIGS-solpanel.* Självständigt arbete inom system i teknik och samhälle, Uppsala universitet, Institutionen för teknikvetenskaper.

Bolo, M. (2006). *Knowledge, Technology and Growth: The Case Study of Lake Naivasha Cut Flower Cluster in Kenya.* World Bank.

Boyle, G. (2004). *Renewable Energy: Power for a sustainable future.* 2nd ed. Bath Press, United Kingdom

Börjesson, D. Personal Communication. 11 & 24 April, 2013.

Cool Logistics Africa (2012). *Cool Logistics Africa looks at growing sea freight potential for East and West African perishables.* Available online: http://www.coollogisticsafrica.com/news_/news/cool_logistics_africa_looks_at_g?blid=73 (2013-05-20)

DEFRA (2012). *2012 guidelines to Defra/DECC's GHG conversion factors for company reporting: Methodology paper for emission factors.* Available online: https://www.gov.uk/government/publications/2012-guidelines-to-defra-decc-s-ghg-conversion-factors-for-company-reporting-methodology-paper-for-emission-factors (2013-04-12)

Dolan, C., Opondo, M. & Smith, S. (2003). Gender, Rights & Participation in the Kenya Cut Flower Industry (Natural Resource Institute Working Paper No. 2768). Natural Resources Institute.

EcoTransIT (n.d.) *About*. Available online: http://www.ecotransit.org/about.en.html (2013-04-22)

Energifakta (n.d.). *Solenergi - gratis energi från solen*. Available online: http://energifakta.nu/solenergi/ (2013-04-09)

EPA (2012). *Life Cycle Assessment (LCA).* Availabe online: http://www.epa.gov/nrmrl/std/lca/lca.html (2013-04-18)

FTG (n.d.).*What is F.T.G.* Available online: http://www.ftg.nl/ukhome.html (2013-04-08)

GHG Protocol (2007). *Indirect CO_2 Emissions from the Consumption of Purchased Electricity, Heat, and/or Steam: Guide to calculation worksheets.* Available online: http://www.ghgprotocol.org/files/ghgp/tools/ElectricityHeatSteamPurchase_guidance1.2.pdf (2013-04-08)

Google Maps (2013). Available online: http://www.maps.google.se (2013-05-06)

Go-solar Systems Ltd (2012). *Solar Panels.* Available online: http://www.gosolarltd.com/solar.html (2013-04-16)

Hille, G. et al. (2011). *Grid Connection of Solar PV: Technical and Economical Assessment of Net-Metering in Kenya.* GIZ.

Kenya Embassy (2012). *Kenya Cut Flower Industry*. Available online: http://www.kenyarep-jp.com/business/industry/f_index_e.html (2013-04-15)

Hsu, D.D., O'Donoughue, P., Fthenakis, V., Heath, G.A., Kim, H.C., Sawyer, P., Choi, J-K., and Turney, D.E. (2012) Life Cycle Greenhouse Gas Emissions of Crystalline Silicon Photovoltaic Electricity Generation: Systematic Review and Harmonization. *Journal of Industrial Ecology, 16(S1),* 122-135. DOI: 10.1111/j.1530-9290.2011.00439.x

KPLC (2012). *Power interruptions.* Available online: http://www.kplc.co.ke/index.php?id=146 (2013-04-19)

Maersk Line (2012). *Reefer Rate Restructure; Reefer base rates to increase USD 1500 per FFE effective 1 January, 2013.* Available online: http://www.maerskline.com/link/?page=lhp_news&path=/asia/uae/news20121001

Mekonnen, M.M., Hockstra, A.Y. & Becht, R. (2012). Mitigating the Water Footprint of Export Cut Flowers from the Lake Naivasha Basin, Kenya. *Water Resource Management, 26*(13), 3725-3742. DOI: 10.1007/s11269-012-0099-9

NREL (n.d.). *Simple Levelized Cost of Energy (LCOE) Calculator Documentation.* Available online: http://www.nrel.gov/analysis/lcoe_documentation.html

Photovoltaic Software (2012). *PVGIS.* Available online: http://photovoltaic-software.com/pvgis.php (2013-04-16)

Power by Rays (2013). *Solar Power Ollie.*

pvXchange (2013). *Price Index.* Available online: http://www.pvxchange.com/priceindex/Default.aspx?template_id=1&langTag=en-GB

Regeringen (2013). *Kenya*. Available online: http://www.regeringen.se/sb/d/2574/a/75489 (2013-04-08)

Reid, M.S. (2009). *IATA Perishable Cargo Manual: Handling of Cut Flowers for Air Transport.* UC Davis.

Se.gas-globe (2013). *Bensinpris-kartor.* Available online: http://se.gas-globe.com/maps.phtml (2013-05-06)

SEB (2013). *Valutaräknare.* Available online: http://www.seb.se/pow/apps/Valutaraknare/default.aspx (2013-05-07)

Soil Association (2007). *Air Freight Green Paper: Should the Soil Association tackle the environmental impact of air freight in its organic standards?*

Svarén, A.M. (2002). *Kylkedjan för snittblommor: en kartläggning av distributionen*. Examensarbete, Lunds universitet, Institutionen för Designvetenskaper.

Svensk Solenergi (n.d. a). *Solcellens funktion.* Available online: http://www.svensksolenergi.se/fakta-om-solenergi/Solel/solcellens-funktion (2013-04-09).

Svensk Solenergi (n.d. b). *Drift och underhåll av solcellsanläggningar.* Available online: http://www.svensksolenergi.se/fakta-om-solenergi/Solel/drift-och-underhall-av-solcellsanlaeggningar (2013-04-09).

Swemodule (n.d.) *About the company.* Available online: http://www.swemodule.com/about-the-company.html (2013-04-24)

Swemodule (n.d.) *Product*. Available online: http://www.swemodule.com/product.html (2013-04-24)

The Economist (2008), *Roses are red: Violence and political turmoil threaten a flourishing industry.* Available online: http://www.economist.com/node/10657231?story_id=10657231 (2013-04-08).

Trading Economics (2013). *Kenya exports.* Available online: http://www.tradingeconomics.com/kenya/exports (2013-04-08)

Vattenfall (n.d.) *Vanliga frågor om solceller och solenergi.* Available online: http://www.vattenfall.se/sv/vanliga-fragor-om-solceller.htm?WT.ac=search_success#om_solceller (2013-04-09)

Vonk, H. Personal Communication. 22 April, 2013.

World Bank. (2011). Kenya - Private Sector Power Generation Support Project. Washington D.C. - The Worldbank.

World Resource Institute (2012). GHG Protocol tool for stationary combustion. Version 4.4.