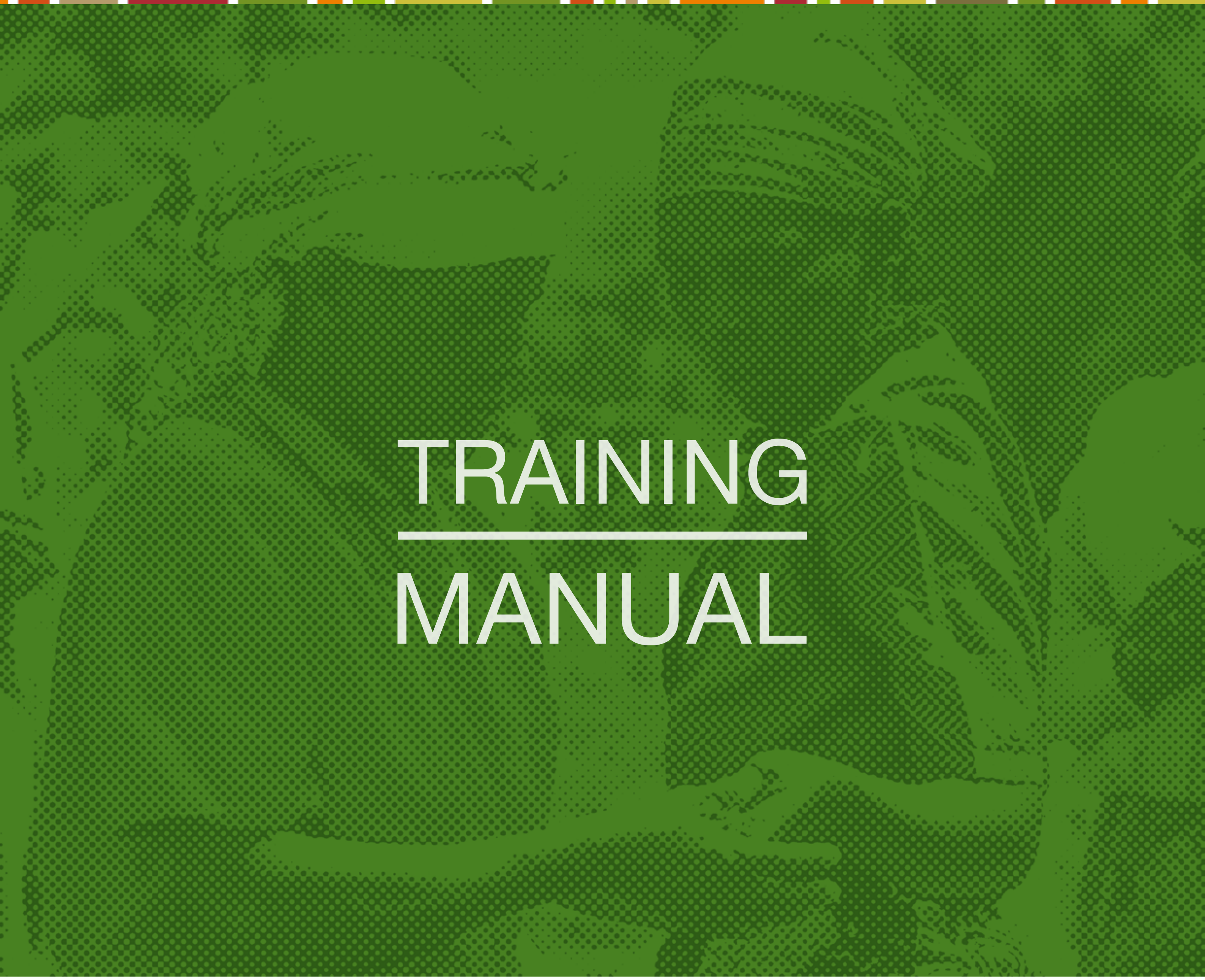

TRAINING MANUAL

- ENVIRONMENTAL MANAGEMENT -

SUSTAINABLE ENERGY MANAGEMENT

COLEACP

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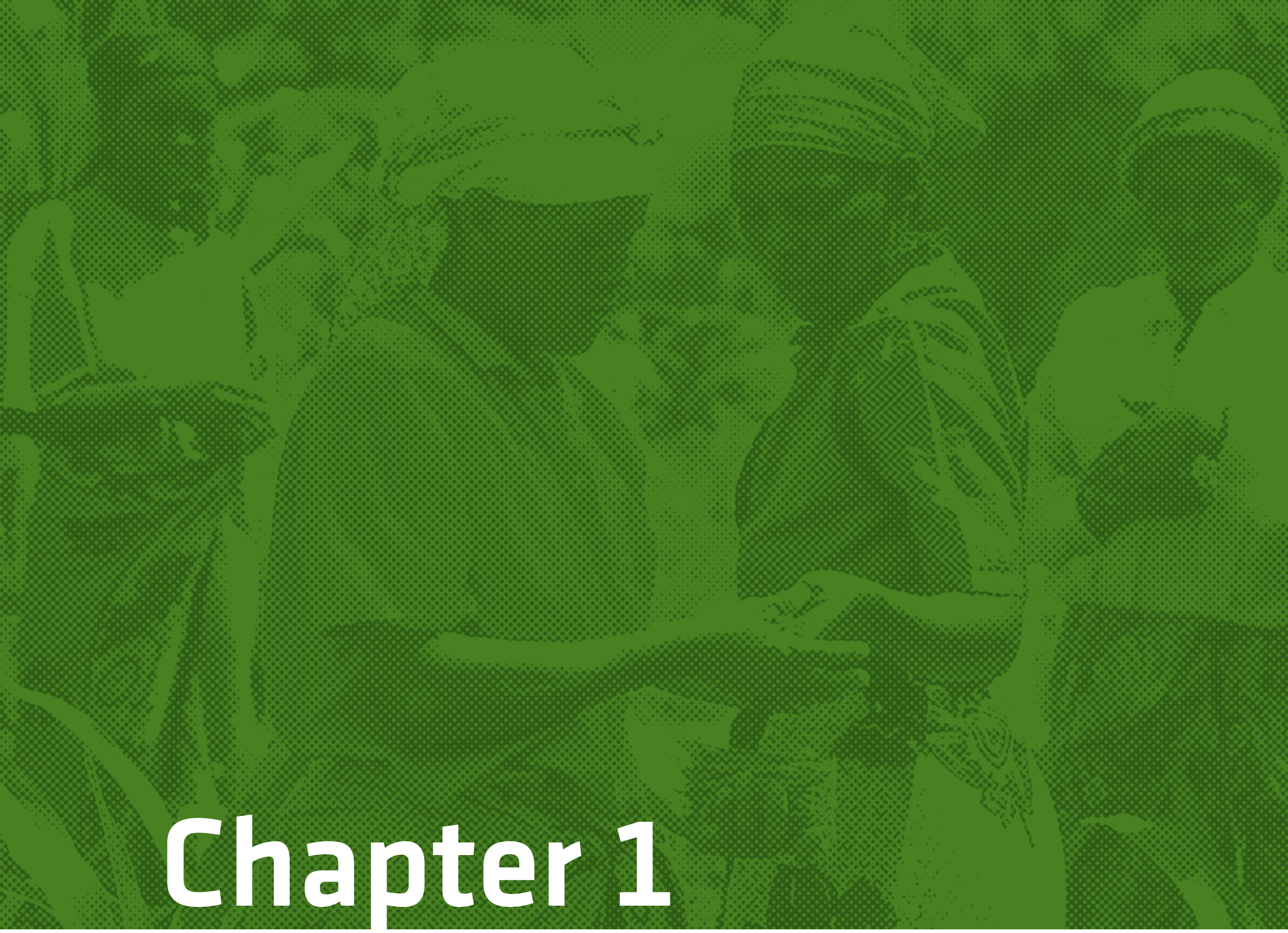


Chapter 1

Energy sources, energy management systems and energy audit

LEARNING OBJECTIVES

By the end of this chapter, the reader/trainer should be able to:

- Understand the **energy challenges related to agricultural production**, and more generally, linked to climate change.
- Understand **energy issues in an agricultural SME.**
- Identify the **energy consumption items of an agricultural operation** and the **sources of that energy.**
- Understand **the requirements of an energy audit.**

1.1. INTRODUCTION

The agricultural sector is facing challenges on many different levels, mostly related to the effects of climate change; and, ever increasing population bases. These **anthropogenic** changes have affected the availability of adequate and quality natural resources – the atmosphere, soil and water.

Never before have farmers had to call on 'innovation' and 'creativity' in order to survive on local, regional, national or global markets. And, to cope with the unprecedented pressure being placed on the planet's life support systems and the impacts of climate change.

Poor communities that depend on agriculture, small-scale producers or processors and medium sized agro-food chain enterprises that lack the mobility and livelihood alternatives are amongst those who are the most disproportionately affected by climate change (IAASTD, 2009). In short, climate change affects the ability of the agricultural sector to ensure **food security** for local populations.

Those most affected currently appear to be farmers and agricultural enterprises from countries with a high dependence on agricultural inputs to **Gross Domestic Product** (the total value of goods and services provided in a country during a one year period) Thus, these nations, which include the ACP countries (signatories to the Cotenou Agreement, 2000), are particularly vulnerable to the effects of climate change and the additional pressure of burgeoning population bases such that predictions for future food security scenarios range from *catastrophic to mildly pessimistic* (Alexandratos, N., & Bruinsma, J., 2012).

These predictions suggest that between now and 2050, the world's population will increase by one-third and that many of these additional 2 billion people will live in the low GDP countries. Yet, at the same time, more people will be living in cities. Consequently, FAO (2013) estimates that agricultural production will have to increase by 60 percent by 2050 to satisfy the expected demands for food given that current income and consumption growth trends continue. Consequently, the agricultural sector really needs to transform itself to feed a growing global population, as well as to provide the basis for continuing economic growth and poverty reduction in countries with lower GDPs. Unfortunately, the impact of climate change will make this task far more challenging under *a business-as-usual scenario* owing to adverse impacts on agriculture and the spiralling costs required to counter this impact.

The cumulative impact of altered patterns of food consumption are directly linked to: economic growth; increased capacities to consume; the emergence of new technologies;as well as the previously mentioned demographic and lifestyle changes all of which has exacerbated rises in CO_2 levels at the global scale and increased **vulnerability** to the impacts of **climate change** (OECD, 2017). The Intergovernmental Panel on Climate Change (IPCC) have recommended that one of the ways to **mitigate** the effects of climate change is to increase energy efficiency over a short space of time which in turn will help to achieve the objective of less than a 2ºC increase in global temperatures (United Nations, The Paris Agreement, 2015).

FAO (2011) suggests that at the global scale the food system accounts for around 30% of the world's total end-use energy consumption – with more than 70% consumed beyond the farm gate which in turn produces about one-fifth of the world's **Greenhouse Gas (GHG)** emissions. Far more alarming is the fact that more than one-third of food produced is either lost or wasted, and with it about 38% of the energy consumed in the agro-food chain.

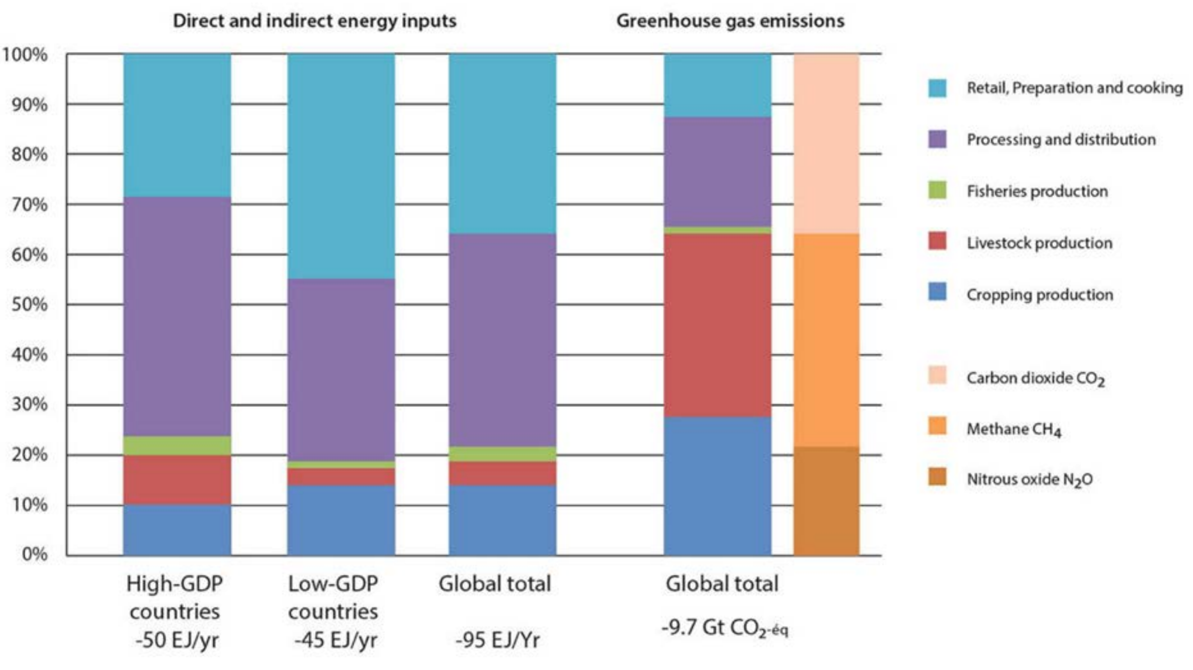


Figure 1 - Global shares of anthropogenic greenhouse gas emissions along the agro-food supply chain and by gas, with breakdown for high- and low-GDP countries – Source FAO 2011

Currently, most of the energy used originates from **fossil fuels** which are proven to be amongst the highest contributors to GHG emissions (refer Figure 1). Consequently, there is a real and urgent need for everyone involved in agro-food chains to become more efficient in their energy use. Whilst energy efficiency can bring **triple wins** – wins for the environment, wins for society and wins for the economy - another relevant reason for owners of large, medium and small enterprises to adapt to energy efficiency is to ensure the sustainability and economic viability of their contributions to the agro-food chain.

This type of **adaptation** includes the wise selection of the energy technologies that maintain production and other added-value activities for agro-food chains.

Nevertheless, there is still a marked reliance on fossil fuels in the countries with high GDPs despite the fact that **Renewable Energy** (RE) technologies have been deployed for at least 3 decades – see Table 1 below.

Table 1: Composition of direct energy use in the OECD area, 1990-2013 (%)

	1990-94	1995-99	2000-04	2005-09	2010-13
Agriculture					
Coal and coal products	3.5	2.7	2.0	1.9	2.0
Oil products	75.7	76.9	72.2	68.6	68.2
Natural gas	8.2	7.6	9.2	10.2	8.9
Biofuels and Waste	1.7	2.0	2.1	2.7	3.8
Electricity	9.6	9.8	13.5	15.8	16.0
Food processing and manufacture					
Coal and coal products	14.2	8.3	8.1	8.6	8.5
Oil products	26.8	21.2	18.0	14.4	8.9
Natural gas	21.8	39.0	40.7	41.2	45.8
Biofuels and Waste	5.1	5.6	5.8	5.1	5.5
Electricity	29.2	24.5	25.9	28.6	28.9
Heat	3.0	1.5	1.5	2.1	2.3

Source: COM/TAD/CA/ENV/EPOC (2016)19/FINAL available at:
http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=COM/TAD/CA/ENV/EPOC(2016)19/FINAL&docLanguage=En

In fact, owing to the volatility in prices and availability of fossil fuels, farmers and others engaged in food production from both the high and low GDP countries urgently need to find the way to reduce on-farm energy consumption. If not, it is very likely that some agricultural communities will fail to survive over the long term.

1.1.1. Interaction between climate change and the use of renewable energy technologies

Energy services are required to meet basic human needs (e.g., at the domestic level: for lighting, cooking, heating/cooling, mobility and communication) and to service production processes. Since approximately 1850, global use of fossil fuels (coal, oil and gas) has increased to dominate energy supply, leading to a rapid growth in carbon dioxide (CO_2) emissions. Generally speaking the increasing use of fossil fuels is responsible for the notable increase in GHG emissions. Increasing levels of GHGs has contributed significantly to the historic increase in atmospheric GHG concentrations. Data collected over recent decades confirms that consumption of fossil fuels accounts for the majority of global **anthropogenic** GHG emissions. Consequently, CO_2 concentrations had increased to over 390 ppm, or 39% above preindustrial levels, by the end of 2010.

Fortunately, there are multiple options that can be applied to help reduce GHG emissions from the energy system while at the same time satisfying the global demand for energy services. Amongst others: energy conservation and efficiency, fossil fuel switching e.g. from coal to natural gas, and/or RE. The preferred option for those engaged in the agro-food chain are RE technologies because if properly implemented they have a high potential to provide **co-benefits** i.e. the benefits derived from lower GHG emissions which contribute to sustainable social and economic development as identified in Figure 2.

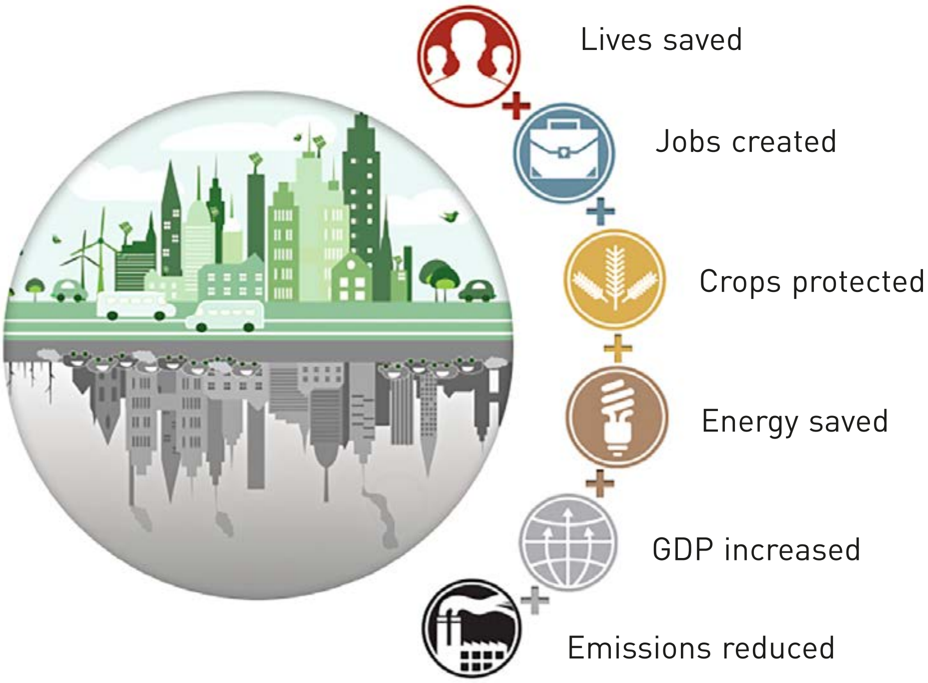


Figure 2 - Benefits derived from lower GHG emissions contributing to sustainable social and economic development (Source World Bank available at https://blogs.worldbank.org/climatechange/files/climatechange/benefits-cover-image-600x419.jpg)

For these reasons the use of RE technologies has increased rapidly in recent years, and their share of overall global energy supply is projected to increase substantially over the long-term. Consequently, governments all over the world are constantly revising RE policies in order to attract the necessary increases in investment in technologies and infrastructure (IPCC 2012). Some fine examples of emerging RE policy making in ACP Countries are in the form of the CARICOM Energy Program (http://caricom.org/energy-programme) adopted for the Caribbean region and Fiji's work with IRENA to prepare a Renewable Readiness Assessment for input to policy (http://www.fdoe.gov.fj/index.php/2014-02-13-22-31-44) at the national level.

This move is significant for those involved in the agro-food chain because it affects decision-making regarding how and where to invest time, energy and money. Also, to assist those involved at the various scales of production and processing to cope with the exponentially increasing requirements for food security.

1.1.2. Climate smart agriculture

As mentioned in the previous section, climate change is already having a marked impact on agriculture and food security due to the increased prevalence of extreme weather events and the emerging unpredictability of weather patterns. Changes in weather patterns can lead to reductions in production and the associated lower incomes in **vulnerable** areas.

These changes can also affect global food prices. Smallholder farmers and pastoralists from countries with lower GDPs are being especially hard hit by fluctuations in food prices as well as. having to cope with the previously mentioned degraded natural resource bases. These farmers and producers often lack the knowledge and the know-how to upscale their approaches to farming and processing. They mostly have limited financial assets and capacity to take the 'risks' involved with the introducing modern energy services into their agricultural operations.

Based on this experience and knowledge, the global NGOs, national governments and other relevant actors involved in encouraging change in the agricultural sector promote **Climate-Smart Agriculture** (**CSA**) as the way forward with which to combat the impacts of climate change.

Climate-smart agriculture (CSA), as defined and presented by FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010, contributes to the achievement of sustainable development goals. It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. It is composed of three main pillars:

1. Sustainably increasing agricultural productivity and incomes;
2. Adapting and building resilience to climate change;
3. Reducing and/or removing greenhouse gases emissions, where possible (FAO, 2013).

The three pillars of CSA:

- **Productivity –** CSA aims to sustainably increase agricultural productivity and incomes from crops, livestock and fish without having a negative impact on the environment. This in turn will raise food and nutritional security. A key concept to increasing productivity is sustainable intensification.
- **Adaptation –** CSA aims to reduce the exposure of farmers and others involved in the agro-food chain, to short term risks, while also strengthening their resilience by building their capacity to adapt and prosper in the face of shocks and long-term stresses. Particular attention is paid to protecting the ecosystem services which ecosystems provide to farmers and others. These services are essential for maintaining productivity and our ability to adapt to climate changes.
- **Mitigation –** wherever and whenever possible, CSA should help to reduce and/or remove GHG emissions. This implies that we reduce emissions for each calorie or kilo of food, fibre and fuel that we produce. That we avoid deforestation from agriculture. And that we manage soils and trees in ways that maximize their potential to act as carbon sinks and absorb CO_2 from the atmosphere.

Key characteristics of CSA:

- **CSA addresses climate change –** contrary to conventional agriculture development, CSA systematically integrates climate change into the planning and development of sustainable agricultural systems (Lipper *et al.*, 2014).
- **CSA integrates multiple goals and manages trade-offs –** ideally CSA offers triple-win outcomes: increased productivity, enhanced resilience and reduced emissions. But it is often not possible to achieve all three. Frequently, when it comes time to implement CSA, trade-offs must be made. This requires us to identify synergies and weigh the costs and benefits of different options based on stakeholders objectives identified through participatory approaches.

(Source: CSA guide. More detailed information available at https://csa.guide/csa/what-is-climate-smart-agriculture)

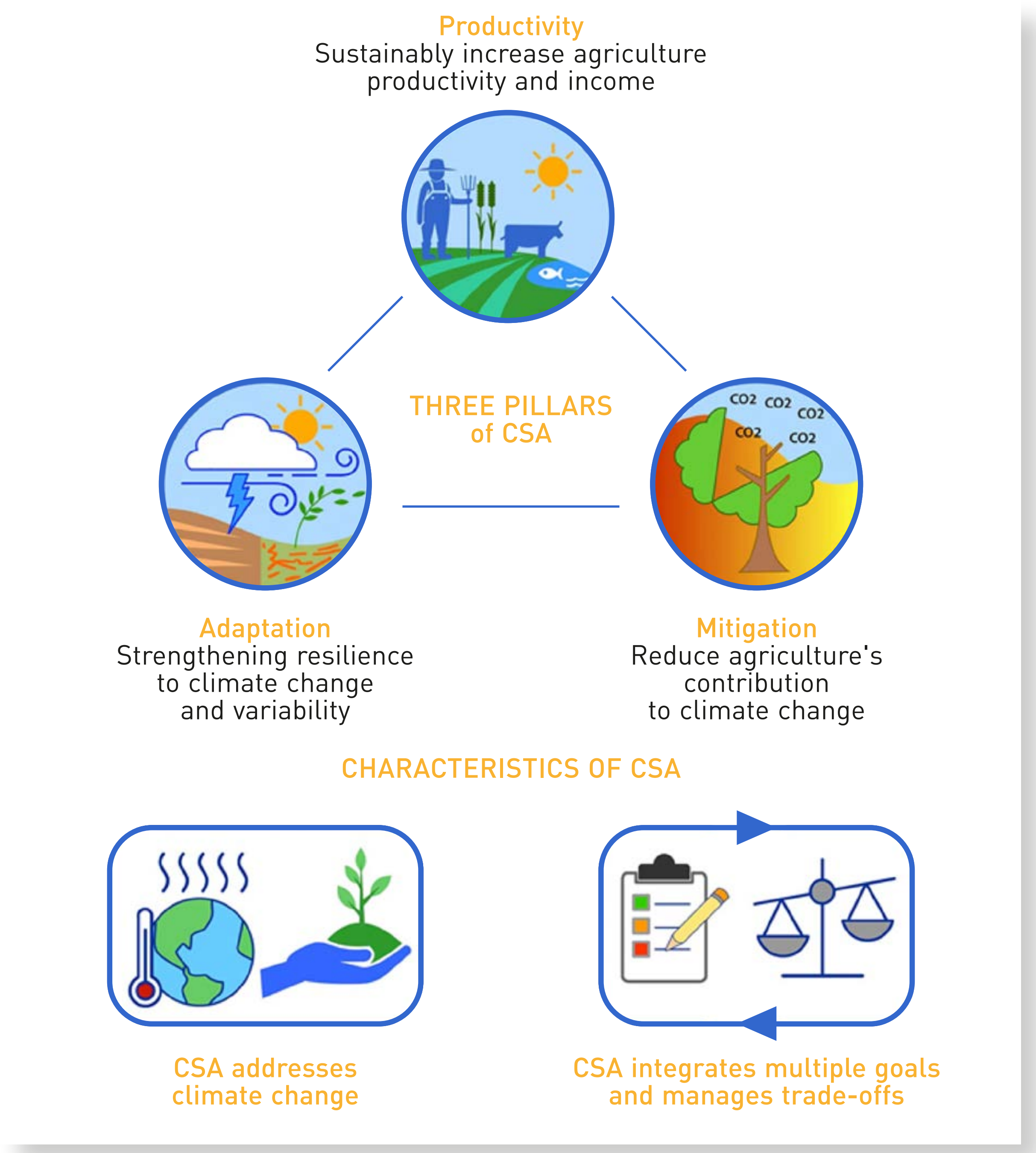


Figure 3 - Pillars and Characteristics of CSA

A good example how this theory has been translated into practice comes from Grenada, where a switch was made from reliance on diesel powered facilities to dry cocoa beans to RE in the form of a pilot solar drying system. The **co-benefits** come in the form of reduced GHG emissions and a more cost effective and sustainable approach to drying cocoa beans.

Solar crop dyer

Heavy rains during traditionally dry seasons have forced Grenada's cocoa farmers to consider alternatives to passively drying the beans outdoors. The Grenada Cocoa Association (GCA) thus began using diesel powered facilities to dry the beans indoors; however, the costs ($30,000) and environmental impact were unsustainably high. With funds from the GEF Small Grants Programme, a pilot solar drying system at Mt. Horne, the largest drying station in the country, is helping them to manage the unpredictability of local climatic conditions in a clean, cost effective and sustainable manner.

An added long-term benefit from this example of CSA in practice is that local workers were trained in solar technology installation, and have held workshops to train the employees of the cocoa drying stations to run the system and to monitor its success. In other words, capacity to adapt to climate change has been increased. In addition, this pilot project will be used to inform future efforts at drying different agricultural commodities throughout Grenada, Carriacou and Petite Martinique. Thus, **the co-benefits** of this switch from a reliance on fossil fuels to RE will assist with **adaptation** for climate change for not only Grenada but will also help to lower the cumulative impact of GHG emissions across to the Caribbean region and build regional capacity in RE expertise.

(Source: ICIA 2017, Climate Smart Agriculture in the Eastern Caribbean States A Compendium of Stories from Farmers, Solar crop dryer for climate resilience. Grenada Coca Association, Grenada)

1.1.3. Energy smart food systems

As previously discussed, there is an urgent requirement for agricultural sectors to reduce the reliance on fossil fuels. The way forward for those who produce behind the farm gate and those who process beyond the farm gate is to up-scale to **energy-smart food systems**. These systems improve energy efficiency, increase the use and production of renewable energy, and broaden access to modern energy services in agro-food chains.

According to the FAO (more detailed information is available at http://www.fao.org/energy/home/en/) **energy smart food systems** should address the following issues:

- Energy needed to ensure food security
- Technologies related to CSA
- Energy poverty in rural development
- Contribute to the development of green and inclusive food value
- Contribute to safe access to sustainable energy in emergency/rehabilitation settings

It is important to note that if handled properly, any increase in energy consumption - even if based initially on fossil fuels - may result in lower absolute GHG emissions.

Improved access to energy usually reduces emissions per unit of food production or per unit of gross domestic product (GDP). Nevertheless, the overall and long-term effect of increased energy access on climate change mitigation should be assessed according to a county's or a community's rate of development in line with the development model that is being followed. Bearing in mind that it is not always the case that there is a **trade-off** to be made between energy access and climate change mitigation

Switching from fossil fuels to RE can bring lower GHG emissions at any point along the agro-food chain. The example below comes from behind the farm gate but extends out to impact veterinary and pharmaceutical services. It is quite safe to assert therefore that the switch from electricity to solar energy powered refrigeration rooms for storage of vaccines provides significant co-benefits, not only to the herders and professionals involved but also to the wider economy at local, regional and national levels.

Solar cooling for storing livestock vaccine in Angola

Animal husbandry is an important source of livelihood in rural Angola and a major agricultural activity. As a consequence, animal service delivery has a direct impact on the socio-economic conditions of herders. The Strengthening of Livestock Services in Angola (SANGA) project, led by the FAO and co-funded by the European Union (EU) and the Institute of Veterinary Services (ISV) Angola provided technical assistance to the livestock keepers and animal health and veterinary technicians to manage livestock and maintain animal health. The livestock in Angola are vulnerable to diseases due to lack of reliable veterinary services and access to vaccination, and vaccines are required to be stored in specific temperatures to survive. The lack of access to energy hampers the storage and distribution of these vaccines across rural Angola resulting in loss preventable animal life. The project aimed at increasing the availability of medicines in the veterinary support system that would result from the involvement of herders.

In 2011, the project installed solar energy systems in refrigeration rooms in 15 municipal veterinary pharmacies. This included the installation of four PV systems to power veterinary centres, including cold storage rooms, as well as around 15 absorption refrigerators to store vaccines in different villages. Solar energy systems and solar coolers have made vaccines more available and have provided herders with the right tools to treat their animals, thus reducing livestock mortality (and consequently, a waste of natural resources).

FAO, 2011. Veterinary help for livestock herders brings relief to Angola. Available online at http://www.fao.org/ in-action/veterinary-help-for-livestock-herders-brings-relief-to-angola/en

Synergy between CSA and Energy-Smart Food Systems can be created through value-added practices that lower emissions embedded in the production of agricultural outputs, lessen the reliance on fossil fuels and enhance the productivity and resilience of agro-ecosystems (FAO, 2013). As there are numerous other synergies between CSA and energy-smart food, climate benefits can and do often accrue through the development of **Energy-Smart Food Systems**. Once again, combining these objectives may also require some trade-offs. These linkages are often quite complex and context specific, and as such, far more research is needed to identify generic trade-offs, if any. Nevertheless, all of these aspirations lead nowhere unless countries can guarantee farmers and others involved in the agro-food chain access to sustainable energy which is the aspiration of the United Nation's SE4All initiative.

1.1.4. Sustainable energy for All – SE4All

The objectives of SE4All initiative are outlined as follows:

The global energy transition requires a rapid increase in energy productivity, a new generation of institutions to manage our energy systems, an integrated approach to energy that embraces centralized and decentralized sources, and ever-increasing share of renewables in the mix. And the energy transition must be a 'just' transition. We must not leave anyone behind.

It is unconscionable that in 2016 there are more than 1 billion people who still have little or no access to electricity and over 3 billion people who do not have access to clean cooking.

Sustainable Energy for All is driving the kind of action we need to put the world on a "well below 2C pathway" with sustainable energy while lifting over a billion people out of poverty in support of SDG 7 and the Paris Agreement.

As a global platform, Sustainable Energy for All empowers leaders to broker partnerships and unlock finance to achieve universal access to sustainable energy, as a contribution to a cleaner, just and prosperous world for all. We marshal evidence, benchmark progress, amplify the voices of our Partners and tell stories of success and connect stakeholders.

Access to constant energy supply is of critical importance to rural communities and those involved in the agro-food chains all over the world. However, the source of this energy needs to be well thought out and much planning is required on the part of those from both behind and beyond the farm gate in order to ensure the sustainability and economic viability of the energy supply for their particular production or processing activity.

1.1.5. Sources of energy

In the past, particularly in countries with low GDPs there has been a tendency to rely on fossil fuels to provide the energy for both on farm and off farm activities because they have been easily accessible. For example, in the East African countries at small scale farming level there is still the tendency to rely heavily on fossil fuels because they are more readily accessible. By definition fossil fuels are formed by natural processes, such as anaerobic decomposition of buried dead organisms, containing energy originating in ancient photosynthesis. The age of the organisms and their resulting fossil fuels is typically millions of years, and sometimes exceeds 650 million years. Fossil fuels contain high percentages of carbon and include petroleum, coal, and natural gas. Other commonly used derivatives include kerosene and propane. Fossil fuels range from volatile materials with low carbon to hydrogen ratios like methane, to liquids like petroleum, to non-volatile materials composed of almost pure carbon, like anthracite coal. Methane can be found in hydrocarbon fields either alone, associated with oil, or in the form of methane clathrates (far more detailed information relating to fossil fuels and the use of is available at Wikipedia English). When used alone fossil fuels are not generally recognised as providing co-benefits. The benefits generally come in the form of **trade-offs** by removing one source of GHG emissions and replacing it with a source that is lower in GHG emissions, i.e. contain the GHG emissions at source.

A good example of how the burden of pollution can be placed onto the polluter comes in the form of small to medium sized enterprises involved in the agro-food chain being persuaded that the costs of a simple 10 percent reduction in GHG emissions is possible. Of course, the benefits even beyond the farm gate such as the economic and other benefits need to be quite notable over the long-term. Placing the responsibility on the producer of the emissions is far more reliable than trying to convince a local community from a low GDP country to change to diets that rely on the use of fresh and local produce that is low in GHG emissions – given that many of these countries are still poverty trapped. This approach could also help reduce overall demands for energy, water and land. The benefits to the enterprise can be more easily identified e.g. despite higher initial start-up costs energy consumption costs could be lower over the long-term and the triple wins are more clearly recognisable at a smaller and localised scale.

In direct contrast to the fossil fuels that are the source of high GHG emissions RE technologies often widely used in CSA and energy smart food systems tend to be adapted from **wind, solar, hydro, geothermal, and biomass resources are considered to more likely provide co-benefits.** More recently, **bioenerg**y produced from food processing plants is being used although the topic is still being discussed and far more research is needed to identify both the positive and negative environmental and other costs for this energy. Also, in the future it may be possible to harness far more **tidal energy** for use in fisheries and aquaculture. Consequently, to make the gradual shift to energy-smart food systems farmers, small and large enterprises or even agricultural communities should strive to identify the mix of appropriate energy technologies, equipment and facilities that improve energy efficiency, reduce GHG emissions and contribute to food security.

Figure 4 - Sources of RE technologies

The nature of this mix will depend on natural conditions, infrastructure and skills available in the labour force. There are many RE technologies that can be part of CSA and energy- smart food systems, including: wind mills, solar collectors, photovoltaic panels, biogas production units, power generators, equipment for bio-oil extraction and purification, fermentation and distillation facilities for ethanol production, pyrolysis units, hydrothermal conversion equipment, solar-, wind or bioenergy-operated water pumps, renewable energy-powered vehicles, monitoring systems, information and communication technologies (ICT), cooking stoves, equipment for water supply, distribution and purification. These technologies add value to production near the source of raw materials (FAO, 2013) which is always the preferred with the mitigation of any environmental impact.

Before making any decisions regarding the appropriate types of energy mixes it is important to investigate, cost and plan to determine if the selected mix of energy types provides benefits and trade-offs are required. For example, there are major differences between attempting to reduce, say, tractor fuel demand through energy efficiency measures in industrialized agriculture and introducing tractors or machinery into traditional agriculture in order to improve productivity, reduce losses and reduce drudgery.

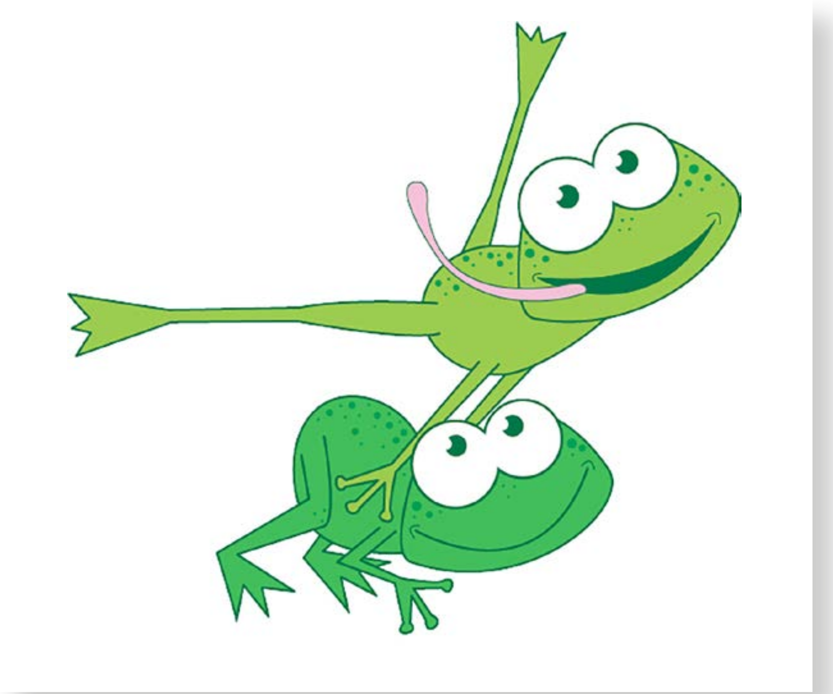


Figure 5 - Leaping frogs

Utilizing good practice, Leapfrog Technologies whenever possible ensures that the energy services needed (for cultivation, transport, refrigeration, etc.) are provided at low costs and with minimum environmental impacts. The same argument holds for all aspects of food production and processing. Similarly, animals used for transport and cultivation can be replaced by tractors. Whereas this involves the combustion of an increased amount of fossil fuels, and hence more GHGs emitted, it offsets the number of draught animals needed and therefore their demand for animal feed (which competes for land with human food production). Particularly for cattle, this reduces their enteric methane emissions. As a result, the CO_2-eq emissions from tractor fuel combustion are a small price to pay (Simm, Flammini, Puri, Bracco, 2015). These CO_2-eq emissions could well be eliminated from another production or processing activity over the entire scale of an agro-food chain.

1.1.6. The relative scales of food systems

The spectrum of food systems ranges from behind the gate basic subsistence smallholder farmers growing food for their own consumption, to beyond the gate large commercial, corporate farms supplying huge supermarket chains across the world. All of these systems are dependent on energy whether it is sourced from fossil fuels or RE sources. Electricity is one of the key energy carriers used in many activities on farms, in food processing plants and during the manufacture of fertilizer, machinery, equipment, and building materials. Yet, there are still small remote rural communities that are unable to access modern energy services mostly due to poor road infrastructure or the fact that electricity grids are remote.

Even where electricity distribution lines have been built, supply may be very unreliable with frequent outages and fluctuations in power quality – as is the case in many of the ACP countries. In these remote locations the cost of liquid fuels remains relatively high due to delivery costs. Consequently, diesel-generation sets are often employed to produce electricity. More recently and wherever possible RE systems have been developed such as small-scale hydro, wind, and solar power systems to overcome the reliance on fossil fuels. Table 2 details the relative scale of dependence on fossil fuel across a typical agro-food chain, as well as the intensity of the energy inputs at each of the various scales of the production and processing of food.

Table 2: Relative scale of dependence on fossil fuel across a typical agro-food chain

Scale of Producer	Overall input intensity	Human labour units	Animal power use	Fossil fuel dependence	Capital availability	Major food markets	Energy Intensity
Subsistence level	Low	1-2	Common	Zero	Micro finance	Own use	Low
Small family unit	Low	2-3	Possible	Low/ medium	Limited	Local fresh/ process/own use	Varies from low to high
	High	2-3	Rarely	Medium/ high	Limited	Local fresh/ regional process/ own use	Varies from low to high
Small business	Low	3-10	Rarely	Medium/ high	Medium	Local/regional/ export	Varies from low to high
	High	3-10	Never	High	Medium	Local/regional/ export	Varies from low to high
Large corporate	High	10-50	Never	High	Good	Regional process/export	Varies from low to high

Source: Reproduced from FAO "Energy Smart Food for People and Climate" Issue Paper 2011. P.5 Simplified typology of typical 'small' and 'large' scale farms and fisheries based on qualitative assessments of unit scale, levels of production intensity, labour demand, direct and indirect fossil fuel dependence, investment capital availability, foods markets supplied and energy intensity.

The **value chain** approach can be applied to identify the energy inputs across the various scales along the agro-food chain. Each step along the way presents a different challenge to providing the relevant energy services efficiently, cost effectively and where feasible, using low carbon fuels. An overview of the different types of direct and indirect energy inputs required across the various scales of an agro-food chain is provided in Figure 6 below (FAO: Sims, Flammini, Puri & Bracco, November 2015). The value chain approach also helps energy users to identify the opportunities to incorporate clean - or RE technologies - or even mixes of fossil fuels and RE along the various points of the value chain that can provide co-benefits over the long-term.

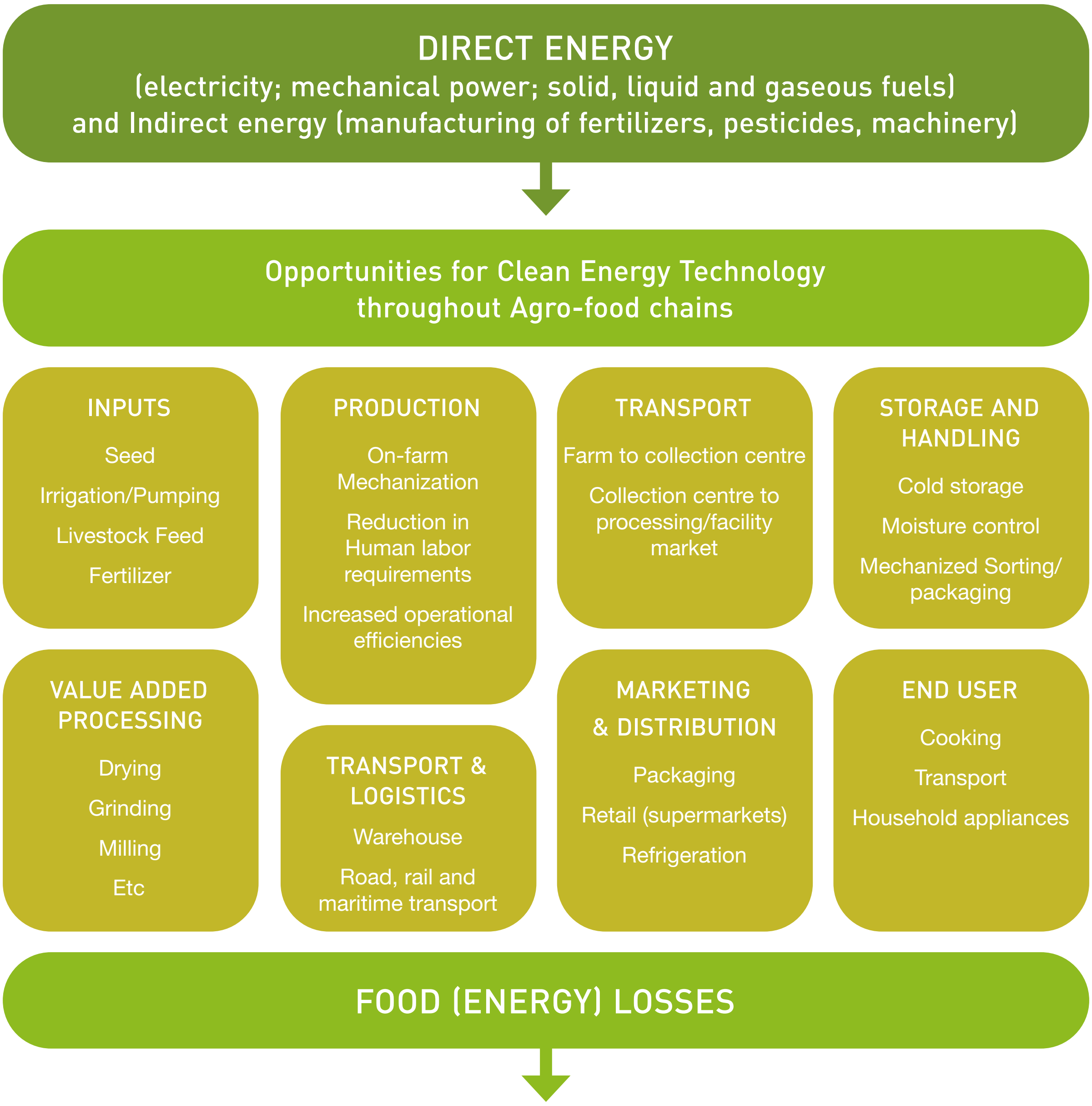


Figure 6 - Food value chains in the agricultural production and processing sectors where clean energy technologies can be applied to provide the desired energy services but with lower environmental impacts including reduced GHG emissions.
Source: Reproduced from FAO – Sims, Flamini, Puri & Bracco, November, 2015

1.2. ENERGY NEEDS AND BASIC ENERGY ECONOMICS

Agriculture and energy have always been closely inter-linked, however, the linkages are changing and growing stronger over time. The ‘mechanization of agro-food chains’ means that nowadays both energy inputs and outputs are far greater than at any time in the history agriculture. On and off farm and food processing enterprises have also become more intensive and nowadays are serviced with modern energy services that are largely dependent on fossil fuel inputs. The subsequent linkages between energy and agro- food systems have strengthened as agriculture has become increasingly reliant on chemical fertilizers, irrigation and machinery. Post-harvest activities, such as food storage, processing and distribution, are also energy-intensive.

Consequently, higher and volatile energy costs have a direct impact on agricultural production costs and food prices. During recent times, the increased use of energy by the agricultural sector has significantly contributed to feeding the world. Energy from fossil fuels has helped to increase farm mechanization, boosted fertilizer production and improved food processing and transportation. Between 1900 (when energy inputs were limited to low-level fertilization and rudimentary mechanization) and 2000, the world’s cultivated area doubled, but the energy used in edible crops expanded six-fold. This greater productivity was made possible by an 85-fold increase in energy input per hectare (Smil, 2008).

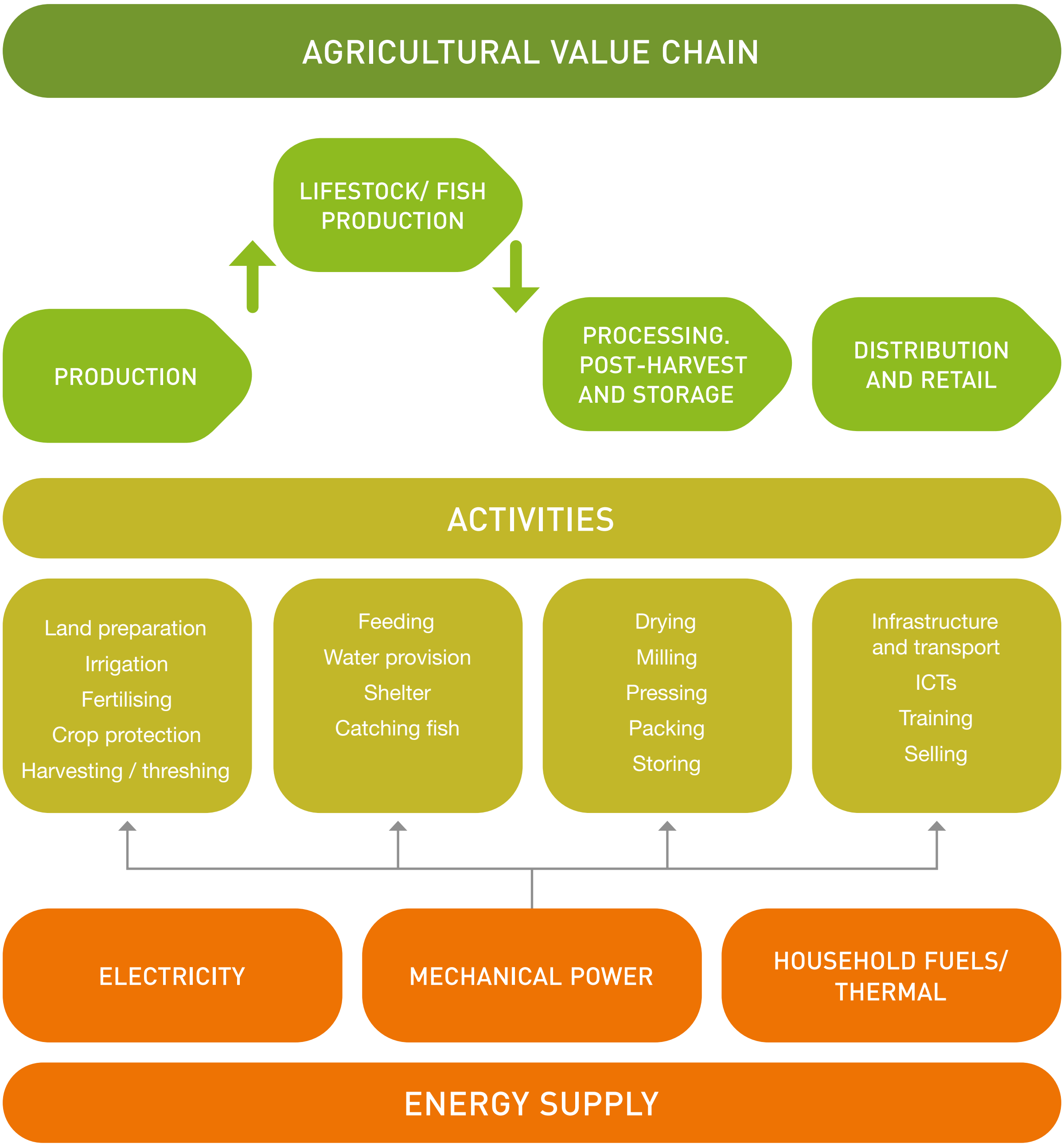


Figure 7 - Energy Inputs for a series of activities within each link of the agro-food chain.
Source: Practical action (2012) Adapted from FAO 2009 and UTZ (2011).
See practicalaction.org/

The increase in energy inputs occurred in an area of cheap oil and where there were few concerns about climate change. However, since then times have changed. Prices for nitrogen fertilizers and other fossil fuel-dependent inputs are closely related to the price of crude oil. Rising and volatile oil prices translate into higher and fluctuating food production costs. As a result of these rising and volatile oil prices farmers, in particular smallholder farmers, are the first to feel the impact. The use and application of two basic energy economic tools can be deployed to help enterprises of all shapes and sizes involved in the agro-food chain to make the wisest decision relating to the costs and benefits of energy inputs across the different scales of production or processing activities. The tools most commonly applied are Cost-Benefit Analysis and Life Cycle Assessments.

1.2.1. Energy economics – cost-benefit analysis, life cycle cost assessment, life cycle assessment

Financial and economic analysis is more of an art than a science for these aspects of energy management, that is, with an operational lifetime of more than 15 years. Generally speaking, energy management with short pay-back periods do not always require a sophisticated appraisal. Depending on the size of the enterprise and the purpose of the proposed investment, there are three types of methodologies commonly applied to determine benefits versus the costs of investments into energy technologies. These are commonly known as **Cost-Benefit Analysis** (CBA), **Life Cycle Cost Assessment** (LCCA) and **Life Cycle Assessments** (LCA).

1.2.1.1. Benefit analysis

Cost-Benefit Analysis (CBA) sometimes called Benefit Costs Analysis (BCA), is a systematic approach to estimating the strengths and weaknesses of alternatives (for example in transactions, activities, functional business requirements or projects investments); it is used to

determine options that provide the best approach to achieve benefits while preserving savings. The CBA is also defined as a systematic process for calculating and comparing benefits and costs of a decision or in the case of energy technologies, a project that requires investment. Table 3 below describes the basic analytical steps involved to arrive at an outcome that indicates whether or not the investment – over a determined period of time – provides the required benefits.

Thus, CBA is applied broadly as an economic tool for two main purposes:

1. To determine if an investment/decision is sound (justification/feasibility) – verifying whether its benefits outweigh the costs, and by how much;
2. To provide a basis for comparing projects – which involves comparing the total expected cost of each option against its total expected benefits.

CBA is related to (but distinct from) cost-effectiveness analysis. In CBA, benefits and costs are expressed in monetary terms, and are adjusted for the time value of money, so that all flows of benefits and flows of project costs over time (which tend to occur at different points in time) are expressed on a common basis in terms of their net present value.

A simple example takes the form of replacing inefficient lighting with efficient LED lights. This action should result in a Cost/Benefit ratio that is greater than 1 and is therefore financially attractive for the company since the benefits outweigh the costs. The steps taken to arrive at the Cost/Benefit Ratio take the following form:

1. Identify the costs and the benefits – what counts, who counts and the time period
2. Calculate the costs and the benefits – methods of calculation and discounting future benefits/costs
3. Compare the aggregate costs with aggregate benefits
4. All CBA ratios of 1 or greater indicate the success of the proposal or project.

A more detailed example for the agro-food chain could be to determine if the benefits outweigh the costs for a small landholder who is considering the purchase of a solar dryer. Assume that the small landholder who provides both the labour, capital and operating expenditure to be able produce 4,000 bags of dried bananas and mangos/year. Even though this is a very simple exercise it must be noted that inputs will vary according to the size, location, local labour costs and purpose of the solar dryer i.e. is it drying fruit or vegetables and what type?

In this example the following is assumed:

REVENUE:

- Sale price per bag (with 100g of dried fruit) 1.00$
- Amount of produced and sold bags (pieces) 4,000

COST

CAPEX (Capital expenditure)

- Simple Solar Dryer 1000$
- Build-up (Labour cost) 20$
- Sealing machine for the bags 80$

OPEX (Operating expenditure)

- Cost per bag 0.10$
- Costs per mango (30g) 0.16$
- Costs per banana (30g) 0.10$
- Labour costs (including maintenance) 0.35$/bag

OTHER PARAMETERS

- No land purchase cost or rent payment considered
- Lifetime of project – 10 years
- Discount rate – 10%

- Once this data is established the small landholder can proceed to calculate the profitability of this particular investment as illustrated below:

Table 3: Analytical steps involved in CBA

CAPEX	
Simple Solar Dryer ($)	1,000
Build-up (Labour cost) ($)	20
Sealing machine for bags ($)	80
Total initial investment ($)	1,100
OPEX	
Cost per bag ($)	0.10
Amount of bags per year (pieces)	4,000
Packaging ($)	400
Costs for mangos ($)	1,066.67
Costs for bananas ($)	666.67
Labour cost (incl. maintenance) ($/bag)	0.35
Labour cost ($/year)	1,400
Annual operational cost ($)	3,533.33
REVENUE	
Dried fruit bag (100g) sale price ($)	1.00
Amount of sold bags per year ($)	4,000
Annual revenue ($)	4,000
Annual cash-flow ($)	466.67
Payback period (years)	2.36
Discount rate 10%	0.10
Net Present Value (NPV) ($)	1,767.46
Internal Rate of Return (IRR) (%)	41.06%
Additional calculations	
2000 bags of dried mango slices, 2000 bags of dried banana slices	
1 bag = 100g of dried fruit, either banana or mango	0.48
4000 bags = 400,000g dried fruit	
1 mango (30g) ($)	0.16
1 banana (30g) ($)	0.10
Required bananas for 2000 bags	6,666.67
Required mangos for 2000 bags	6,666.67

N.B. the stated numbers are given as an example and will vary from project to project
Source: Powering Agriculture: An Energy Grand Challenge for Development available at https://poweringag.org/mooc

The applied methods of capital budgeting assess the considered solar dryer project as profitable. The calculated payback time is 2.36 years, which is about one fourth of the estimated project lifetime of 10 years. The NPV is positive and the IRRR is with 41.06% higher than the predefined minimum acceptable rate for this example of 10% (discount rate).

Explanation notes: for calculation of NPV (Net Present Value) and IRR (Internal Rate of Return)

Calculating NPV

$$NPV = \sum_{t-0}^{N} \frac{R_t}{(1+i)^t} + R_0$$

Figure 8 - NPV Equation

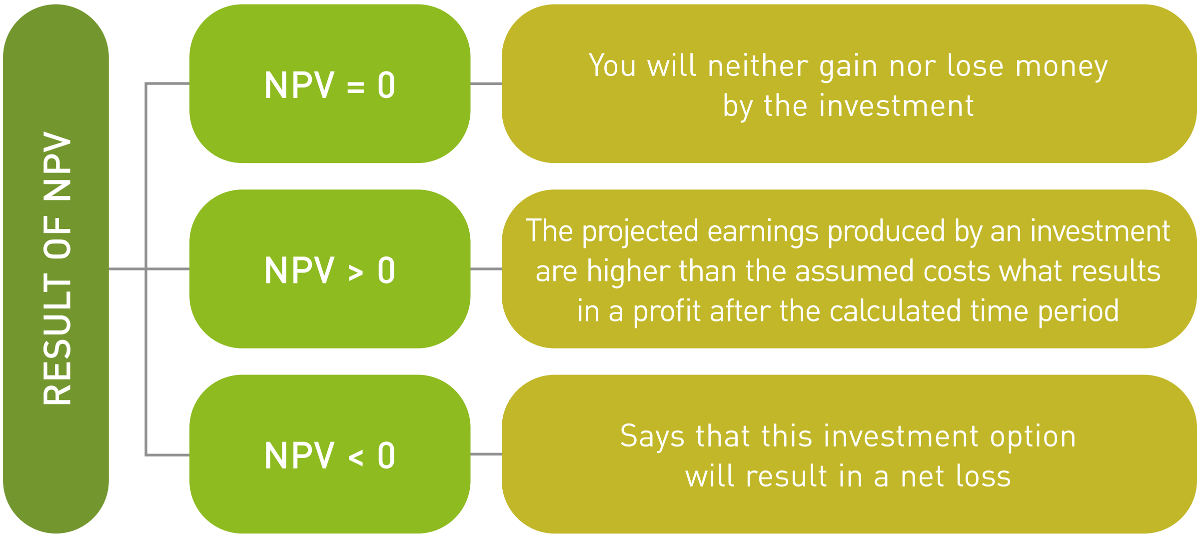
- R_t is the sum of all the discounted future cash flows
- R_0 is the (negative) cash flow at time zero, representing the initial investment
- t is the time of the cash flow, depending on the project lifetime
- i is the discount rate or rate of return.

NPV = (Annual Cash flow / (1.1 to the power 1)) + (Annual Cash flow / (1.1 to the power 2)) + (Annual cash flow / (1.1 to the power 3)) + (Annual cash flow / (1.1 to the power 4)) + (Annual cash flow / (1.1 to the power 5)) + (Annual cash flow / (1.1 to the power 6)) + (Annual cash flow / (1.1 to the power 7)) + (Annual cash flow / (1.1 to the power 8)) + (Annual cash flow / (1.1 to the power 9)) + (Annual cash flow / (1.1 to the power 10)) - initial investment

Table 4: NPV calculation spread sheet

Annual cash flow	Formula constant + discount rate (1 + i)	Time of cash flow (t)	$(1 + i)^t$	Annual cash flow / $(1 + i)^t$
466.67	1.1	1	1.1	424.2455
466.67	1.1	2	1.21	385.6777
466.67	1.1	3	1.331	350.6161
466.67	1.1	4	1.4641	318.7419
466.67	1.1	5	1.61051	289.7654
466.67	1.1	6	1.771561	263.423
466.67	1.1	7	1.9487171	239.4755
466.67	1.1	8	2.1435888	217.705
466.67	1.1	9	2.3579477	197.9136
466.67	1.1	10	2.5937425	179.9215
			SUM	2,867.485
		Initial investment		1,100
			NPV	**1,767.485**

The online calculators such as https://www.calculatestuff.com/financial/npv-calculator can be used as well.



RESULT OF NPV

NPV = 0

You will neither gain nor lose money by the investment

NPV > 0

The projected earnings produced by an investment are higher than the assumed costs what results in a profit after the calculated time period

NPV < 0

Says that this investment option will result in a net loss

Figure 9 - NPV results

Calculating IRR

NPV = 0, Or

$$\sum_{t=1}^{n} \frac{Cf_t}{(1 + IRR)^t} - I_0 = 0$$

Figure 10 - IRR Equation

- Cf_t is the sum of all the discounted future cash flows
- IRR Internal Rate of Return
- I_0 is the cash flow at time zero, representing the initial investment
- t is the time of the cash flow, depending on the project lifetime

Table 5: IRR calculation spread sheet

Annual cash flow	Formula constant	IRR[1]	Formula constant + IRR $(1 + IRR)^1$	Time of cash flow (t)	$(1 + i)^t$	Annual cash flow / $(1 + i)^t$
466.67	1	0.4106	1.410649	1	1.410649	330.8194
466.67	1	0.4106	1.410649	2	1.989931	234.5157
466.67	1	0.4106	1.410649	3	2.807094	166.2467
466.67	1	0.4106	1.410649	4	3.959824	117.8512
466.67	1	0.4106	1.410649	5	5.585921	83.54396
466.67	1	0.4106	1.410649	6	7.879775	59.22378
466.67	1	0.4106	1.410649	7	11.1156	41.98335
466.67	1	0.4106	1.410649	8	15.6802	29.76173
466.67	1	0.4106	1.410649	9	22.11926	21.0979
466.67	1	0.4106	1.410649	10	31.20252	14.95616
					SUM	1,100
			Initial investment			1,100
						0

The calculation for IRR is 41.06%, when having correctly filled in the above mentioned information.

---

[1] This should be expressed as a percentage.

Internal Rate of Return (IRR) is a parameter used in financial analysis to estimate the profitability of potential investments over an assumed period of time. IRR is a discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero. To be able to calculate IRR, NPV must be calculated first. To calculate IRR mathematically, one would need to set NPV equal to zero. However, IRR is difficult to calculate analytically, because of the complexity of the formula. When using the formula, IRR calculations are done through trial and error. Because of the complexity of this type of calculations and the need for accuracy, IRR is generally calculated using special software programs. The online calculators for IRR is https://www.calculatestuff.com/financial/irr-calculator.

The format for the above calculations for NPV and IRR were sourced from Powering Agriculture Sustainable Energy for Food available at https://poweringag.org/mooc

CBA – income and benefit must exceed the investment to make the project worthwhile taking up.

- Identify costs
- Identify benefits
- Compare both

1.2.1.2. Life Cycle Cost Assessment/ Life Cycle Assessment

Life Cycle Cost Assessment (LCCA) is an economic tool applied to determine the most cost-effective option among different competing alternatives to purchase, own, operate, maintain and, finally, dispose of an object or process, when each is equally appropriate to be implemented on technical grounds. For example, an off-grid structure, in addition to the initial construction cost, LCCA takes into account all the user costs, (e.g., reduced capacity at work and residential zones), and agency costs related to future activities, including future periodic maintenance and rehabilitation. All the costs are usually discounted and total to a present-day value known as net present value (NPV).

It is critical that all influential factors are scoped prior to undertaking a LCCA. In other words: what aspects are to be included and what not need be included? However, if the scope becomes too large the tool may become impractical to use and of limited ability to help in decision-making and consideration of alternatives. Conversely, if the scope is too small then the results may be distorted by the choice of factors considered such that the output becomes unreliable or non-specific. Figure 11 below more or less identifies the steps involved in a LCCA when applied to determine the most cost-effective options for a new piece of equipment, material or system. However, it must be noted that neither CBA nor LCCA is applied in such a generic way as identified below.

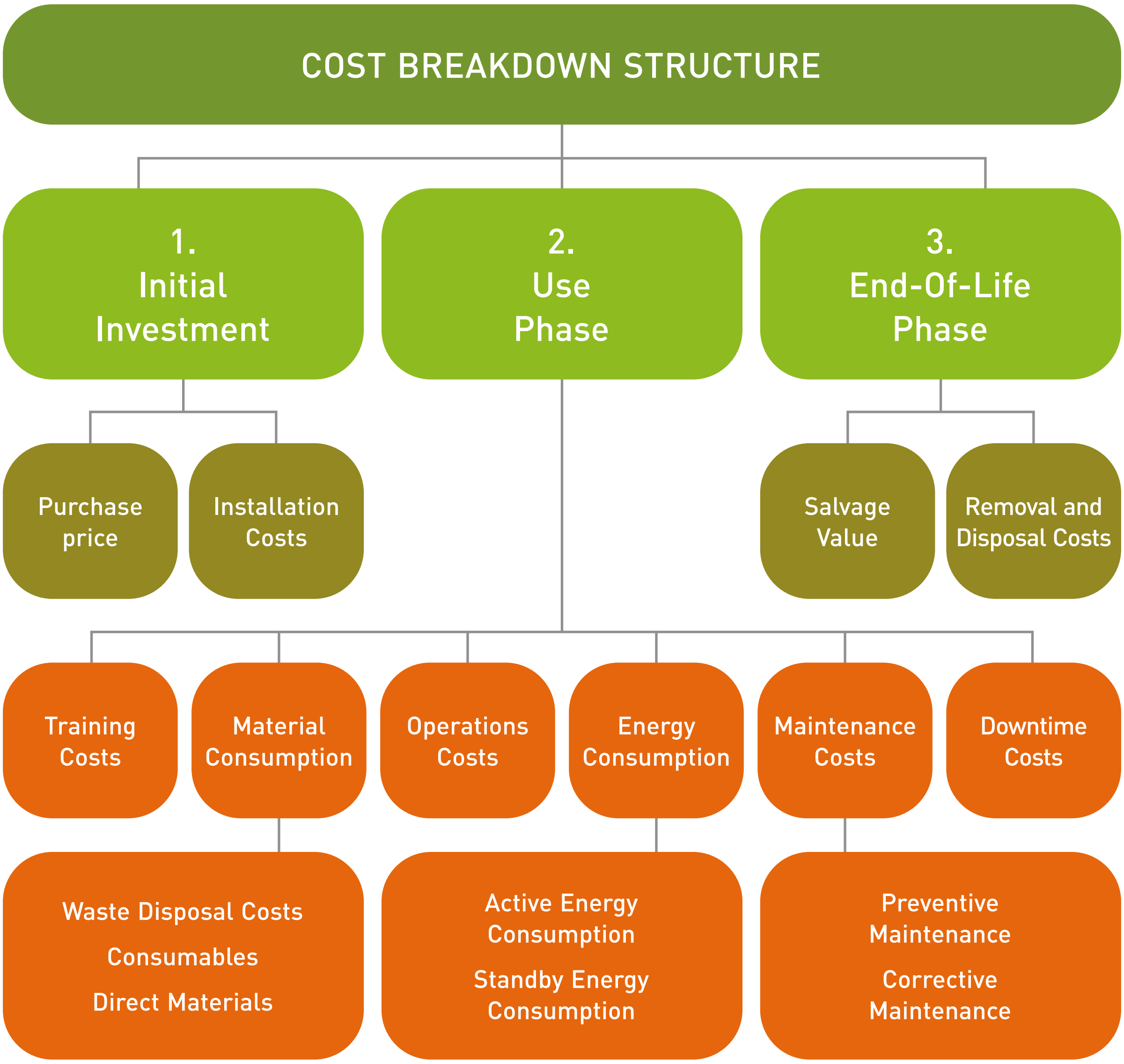


Figure 11 - Generic Cost Breakdown Structure including typical cost components for an Energy Efficiency Project (Source: European Copper Institute, 2005, copperalliance.eu/)

Important to note about the use of LCCA:

- To complete an LCCA, NPV must be calculated. This requires estimation on expenditures for each year of the project, taking into consideration that the identified costs must be adjusted for inflation or be "discounted". NPV is computed by assigning monetary values to benefits and costs, discounting future benefits and costs using an appropriate discount rate, and subtracting the discounted costs from the discounted benefits. Discounted benefits and costs transforms profits and losses in different time periods to a common unit of measurement.
- LCCA is a well-defined procedure for estimating the overall costs of project alternatives. Basically, LCCA consists of adding all the initial and ongoing costs of the structure, product, or component over the time you expect to be using it, subtracting the value derived over time, and continually adjusting for inflation.

Also, it should be noted that the LCCA term implies that environmental costs are not taken into consideration and therefore not included in the final outcome. Whereas the somewhat similar **Life Cycle Assessment (LCA)**, generally has a broader scope and includes all environmental costs. Life Cycle Assessment (LCA) comparisons can provide useful information regarding the long-term environmental footprint as it impacts economic and social benefits over costs for more complex energy investment projects. LCA is applied to derive indicators of the impacts of current food production options and the potential impacts from changing demand, but care is needed in interpreting the results.

Each intervention requires careful analysis. This must be done using a LCA, which includes the intervention's indirect effects, to assess the synergies and trade-offs among the various **Sustainable Development Goals** (Figure 12) related to energy, climate, food security and water security.

Figure 12 - Sustainable Development Goals.
Additional information is available at: http://www.un.org/sustainabledevelopment/

The significant thing to note is that LCAs are generally applied to determine the long-term sustainability of major investments into energy technologies derived from either RE or fossil fuels. LCAs undertaken for electricity generation indicate that GHG emissions from RE technologies are, in general, significantly lower than those associated with fossil fuel options, and in a range of conditions, less than fossil fuels employing CCS. The median values for all RE range from 4 to 46g CO_2eq/kWh while those for fossil fuels range from 469 to 1,001g CO_2eq/kWh (excluding land use change emissions) (IPCC, 2012). Far more detailed information regarding LCA as it applies to agro-food chains is provided in the detail of ISO 14040 and ISO 14043 and in the COLEACP Training Manual for Agriculture, Health and the Environment (pages 96 – 115). Nevertheless, for energy related decisions Figure 13 provides the stages of an LCA as it is applied to determine the footprint of organic Photovoltaics.

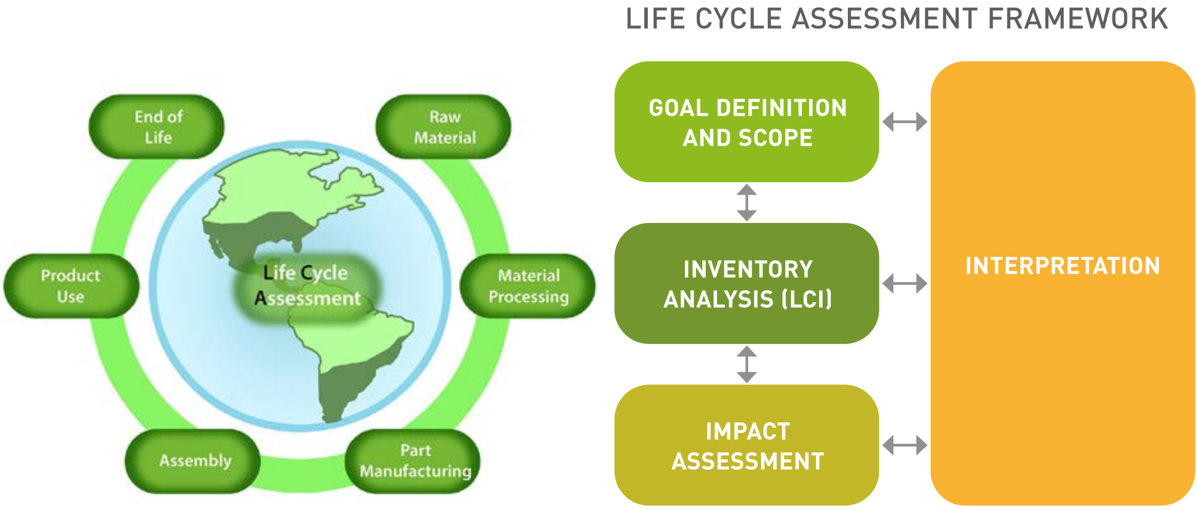


Figure 13 - Stages of an LCA for organic photovoltaics.
Source: Intech – open source material - https://www.intechopen.com/books/third-generation-photovoltaics/life-cycle-assessment-of-organic-photovoltaics

LCCA is a tool used **to determine the most cost-effective** option among different competing alternatives to purchase, own, operate, maintain and, finally, dispose of an object or process, when each is equally appropriate to be implemented on technical grounds.

LCA (which is also referred to as eco-balance, and **cradle-to-grave analysis)**] is a technique used to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling.

1.2.1.3. Application of CBA, LCCA and LCA

1. **CBA – Is simple to use** - The main advantage of CBA is that it is easy to understand. It provides a simple economic tool to determine **whether benefits outweigh costs**. This clarity means that everyone involved in a proposal/Project will understand the monetary nature of the project and the question of its continuance. Its simplicity also means that doing a CBA is easily possible for various scenarios, locations and more. CBA are often mandatory in many countries when decision making for environmental impact needs to be taken into account.

Caution:

- CBA is prone to misuse and misunderstanding regarding the intent for which a CBA is used.
- CBA cannot stand alone in the decision-making process. It cannot change policy and it is not intended to act as a political enforcer.
- Although in some countries the use of CBA to determine the costs or benefits of a Project is obligatory, some studies have illustrated that CBA is limited

when it comes to handling complex investment decisions such as Sustainable Development. If there are social and environmental costs involved it can be difficult or even impossible to arrive at accurate cost estimates.

2. **LCCA – can be used to analyse and get the most out of limited budgets -** LCCA can be used to evaluate corporate policies. The use of LCCA helps to ensure regulatory compliance. LCCA can be used by project managers to take factor in potentially unforeseen costs such as fines for delays, downtime and any safety issues when carrying out the analysis.
   LCCA assists in project management as it evolves during the life-cycle of a project. LCCA can assist project managers to better understand the **true costs** of any project.

Caution:

- **Basic LCCA Calculation**: LCCA is a well-defined procedure for estimating the overall costs of project alternatives. Basically, LCCA consists of adding all the initial and ongoing costs of the project over well defined time period and most importantly **adjusting all costs for inflation**.
- **Relationship between LCCA and NPV:** To complete an LCCA, NPV must be calculated. This requires estimation on expenditures for each year of the project, taking into consideration that the **identified costs must be adjusted for inflation or be 'discounted'.**

3. **LCA –** data used can help to **identify the transfer of environment impacts from one source to another and/or from one life-cycle stage of a project, idea, technology to another.** The use of LCA can lead to innovative solutions, cut costs, help with internal goal setting and communication, ensure compliance with all regulatory requirements and reduce risk.

Caution: Experience has demonstrated that different methodologies can produce varying results. Results can be subjective rather than objective, the validity of data and information used is always of concern, there is still no widely accepted for the application of LCA. Experience has demonstrated that ISO14040 (which relates to the application and usage of LCA) is not yet perfected for environmental declarations and **Carbon Footprints** (full definition of this term in the Glossary).

1.2.2. Efficiency in energy use and selection of the energy source

If energy prices continue to rise, the global food sector will face increased risks and lower profits. The efforts from low-GDP countries to emulate high-GDP countries in achieving increased productivity and efficiencies in both small and large-scale food systems could be constrained due to high energy costs. Existing production and processing practices behind and beyond the farm gate can be adapted so that they become less energy intensive in terms of energy consumption per unit of food produced, and at the same time deliver food in a safe and environmentally sustainable manner. Energy technologies, methods and practices to improve energy efficiency are reasonably well documented and understood. Consequently, there is general consensus that RE technologies, when applied to improve energy efficiency, are inevitably preferable to reliance on fossil fuels.

Nevertheless, improvements in energy efficiency should be applied only when they do not lower productivity, do not restrict energy access and do not threaten rural livelihoods. There are many other direct or indirect technical and social interventions that can be deployed to improve efficiency along the agro-food chain as detailed in Table 6 which are not always directly related to the **Levelized Cost of Energy (LCOE).**

Table 6: Examples of energy efficiency improvements through and indirect technical and social interventions along the agro-food chain.

	Directly	Indirectly
Behind the farm gate	Adopting and maintaining fuel efficient engines	Less input-demanding crop varieties and animal breeds
	Precise water applications	Reducing soil erosion
	Precision farming for fertilizers	Reducing water demand and losses
	Adopting no-till practices	Using bio-fertilizers
	Controlled building environments	Efficient machinery manufacture
	Heat management of greenhouses	Information and communication technologies to identify stock locations and markets
	Propeller designs of fishing vessels	
Beyond the farm gate	Truck design and operation	Truck design and operation
	Variable speed electric motors	Variable speed electric motors
	Better lighting and heating	Better lighting and heating
	Insulation of cool stores	Insulation of cool stores
	Minimizing packaging of food	Minimizing packaging of food
	Improve efficiency of cooking devices and space heating	Improve efficiency of cooking devices and space heating

Source: adapted from FAO, 2011

The net present value of the unit-cost of energy over the lifetime of a generating asset is referred to as **(LCOE)**. It is often taken as a proxy for the average price that the generating asset must receive in a market to break even over its lifetime. The LCOE for many RE technologies is currently higher than existing energy prices, though in various settings RE is already economically competitive. Ranges of recent LCOEs for selected commercially available RE technologies are disparate, depending on a number of factors including, but not limited to, technology characteristics, regional variations in cost and performance, and differing discount rates. Some RE technologies are broadly competitive with existing market energy prices. Whilst many of the other RE technologies can provide competitive energy services in certain circumstances, for example, in regions with favourable resource conditions or that lack the infrastructure for other low-cost energy supplies.

When decisions are made about whether or not to invest in renewable energy technologies and energy efficiency, an agricultural and/or food enterprise would compare any alternative option with the energy source or technology currently used (e.g. fossil fuels). Analysis from many demonstration and commercial renewable energy plants show that costs of projects are very site-specific. Levelized costs of many renewable energy technologies are becoming more and more competitive with current average costs of the fossil-fuel powered electricity, heat and transport fuels that they displace. Moreover, costs for renewable energy technologies are declining as the size of their markets is increasing. Good examples can be found in the different regions of Africa, where rural communities that do not have access grid electricity are able to deploy autonomous renewable energy systems thus avoiding expensive connection costs (Source Powering Agriculture An Energy Grand Challenge for Development available at https://poweringag.org/mooc.) Figure 14 below provides a good illustration of the continuing decline in REs as compared with energy derived from fossil fuel.

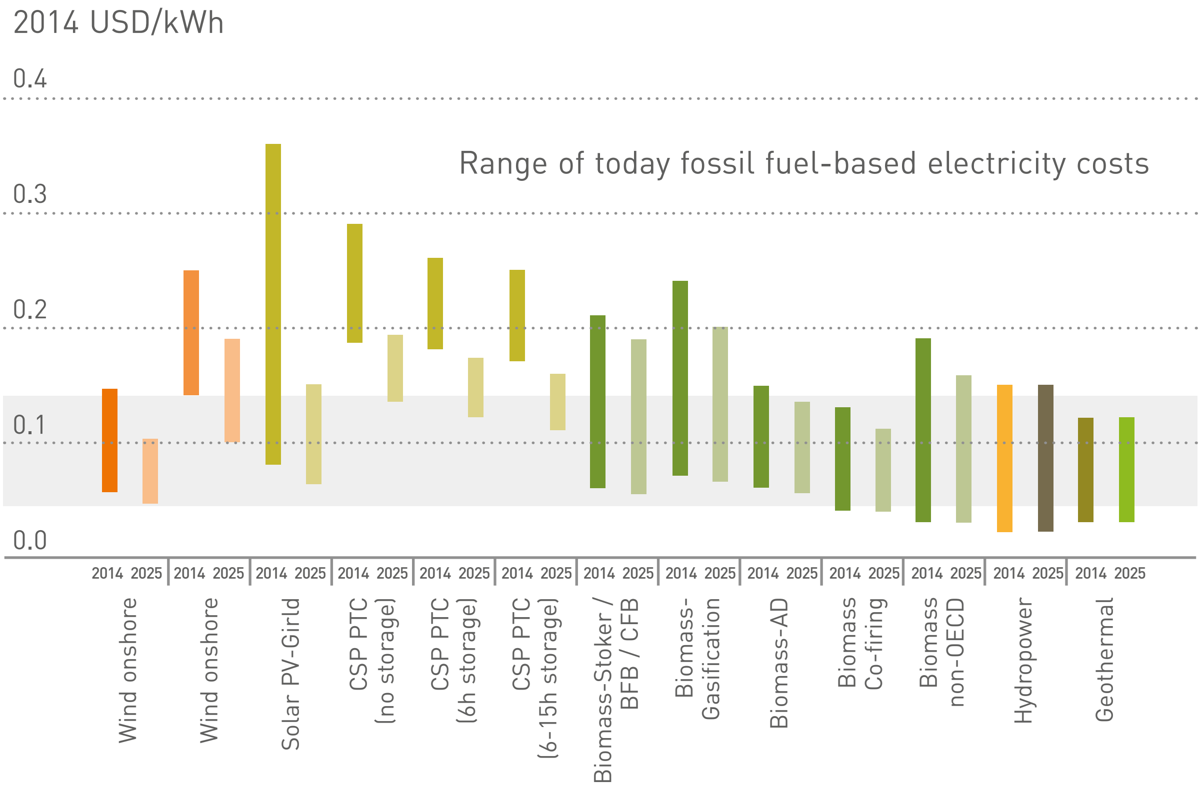


Figure 14 - LCOE ranges by Renewable Power Generation Technology, 2014 and 2015
Source: http://grist.org/climate-energy/renewable-energy-is-getting-cheaper-and-cheaper-in-6-charts/

*The tan coloured horizontal band across the chart is the range of LCOEs for fossil-fuelled power.

The technologies/industries over on the right, the "baseload" renewables, are fairly mature, so their costs are not expected to fall a huge amount. But wind and solar, in all their manifestations, appear to be heading down. By 2025, fossil-fuelled power plants are going to have to clearly justified on all counts, not only environmentally, but economically.as well.

Put simply, the LCOE represents the cost of an energy system over its lifetime. LCOE generally, but not always covers all private costs that tend to accrue further up the line in an agro-food value chain. It does not include those costs located further down the value chain, neither the final cost of delivery to the end-user, integration costs or any other exogeneous costs. Further information can be sourced from http://grist.org/climate-energy/renewable-energy-is-getting-cheaper-and-cheaper-in-6-charts/

The LCOE for a specific RE energy technology is not always the sole determinant of its value or economic competitiveness. The attractiveness of a specific energy supply option depends also on broader economic as well as environmental and social aspects, and the contribution that the technology provides to meeting specific energy services (e.g., peak electricity demands) or imposes in the form of ancillary costs on the energy system (e.g., the costs of integration).

RE technologies are preferred over fossil fuels despite the fact that start-up costs are generally higher than that of fossil fuels. Not only because of lower GHG emissions but also because the cost of most RE technologies continues to decline. In addition, potential and expected technical advances should result in further cost reductions. While significant advances in RE technologies and associated long-term price reductions have become evident over the last decades, periods of rising prices have sometimes been experienced (due to, for example, increasing demand for RE in excess of available supply).

It needs to be noted that the costs and challenges of integrating increasing shares of RE into an existing energy supply system depend on the current share of RE, the availability and characteristics of RE resources, the system characteristics, and how the system is likely to evolve and develop in the future. Whether for electricity, heating, cooling, gaseous fuels or liquid fuels, including integration directly into end-use sectors, the RE integration challenges are contextual and site specific and always include the adjustment of existing energy supply systems (IPCC, 2012). Figure 15 below provides a global view of the installed renewable energy capacity across main regions in 2015.

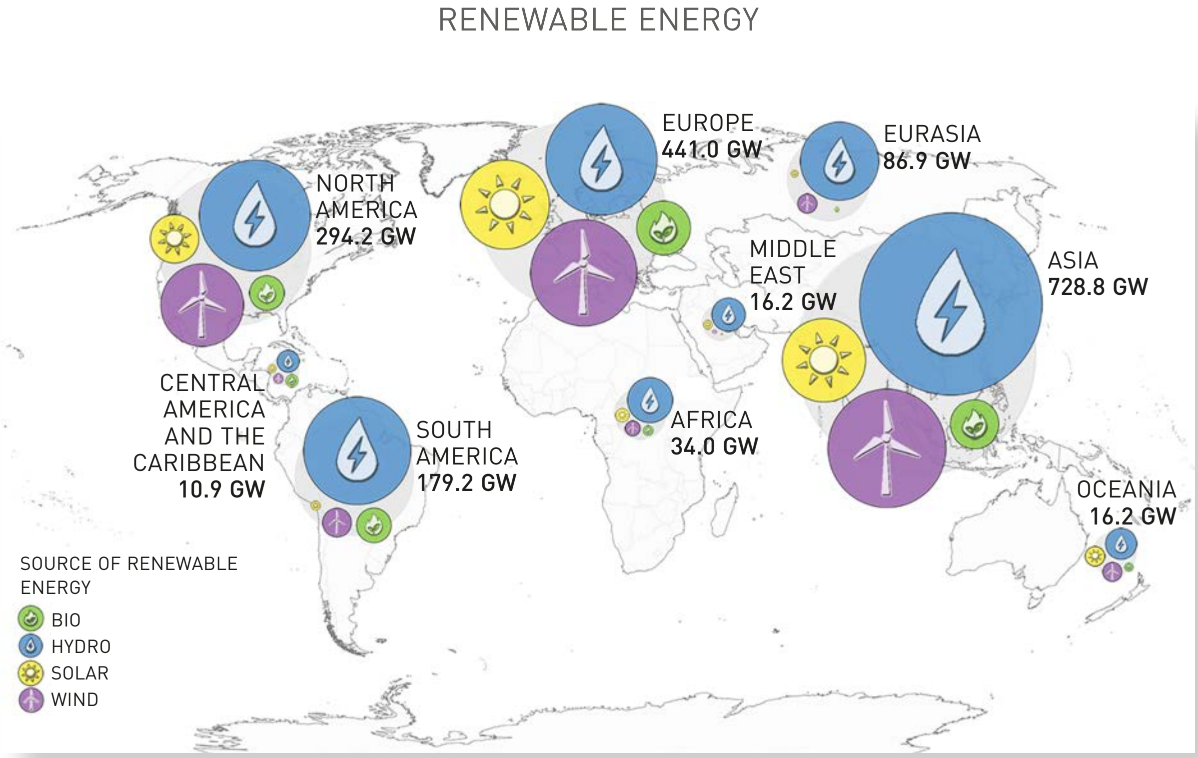


Figure 15 - Global view of the installed renewable energy capacity
Sourced from http://www.viewsoftheworld.net/?p=4904
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1.3. ENERGY MANAGEMENT SYSTEMS

1.3.1. Energy management systems – ISO 50001 and ISO 50002 - the PDCA cycle

Energy management systems

The term 'energy management' means many different things to different people. Asa general rule, it involves the application of at least three principles:

1. Purchasing the energy supply mix at the lowest possible price per unit of useful energy output;
2. Energy conversion management and peak efficiency consumption;
3. Utilisation of most appropriate technology.

It is a useful exercise to take a few minutes to develop a list of the actions or measures associated with each of these principles as they might affect the energy requirements of a small landholder or an enterprise.

- When considering Principle 1, energy purchasing, the enterprise needs to assess the cost per unit of energy available from the source, as well as those issues that influence his or her ability to negotiate favourable energy purchase agreements/contracts.
- The application of Principle 2 means that the farmer/enterprise needs to generate a list of management actions that he/she or someone else on the farm or in the enterprise can take to ensure that energy is used as efficiently as possible.

- Principle 3 may be the most difficult one to deal with in the short term for either farmers or owners of enterprises. As previously discussed in this Chapter, the selection of the appropriate energy source or technology is dependent on many factors.

When thinking about the technological aspects of energy use, it is helpful to categorise measures as follows:

- No cost i.e. housekeeping and operational changes
- Low cost i.e. measures that may require some investment in technology, but that rely extensively on input from people and therefore may include training of staff and energy groups and (re-)consideration of the purchasing policy
- High cost i.e. those measures that require significant investments of capital for the acquisition and installation of new technology.

Energy Management Systems (EnMS) covers the following dimensions:

- **Technical:** Energy-consuming devices and systems that use or convert energy efficiently (or inefficiently).
- **Organisational:** Structures and management systems that can support or hinder the achievement of energy efficiency goals.
- **Behavioural:** Personal values, attitudes and practices of individuals in the organisation that impact on energy use.

DIMENSIONS OF ENERGY MANAGEMENT SYSTEM

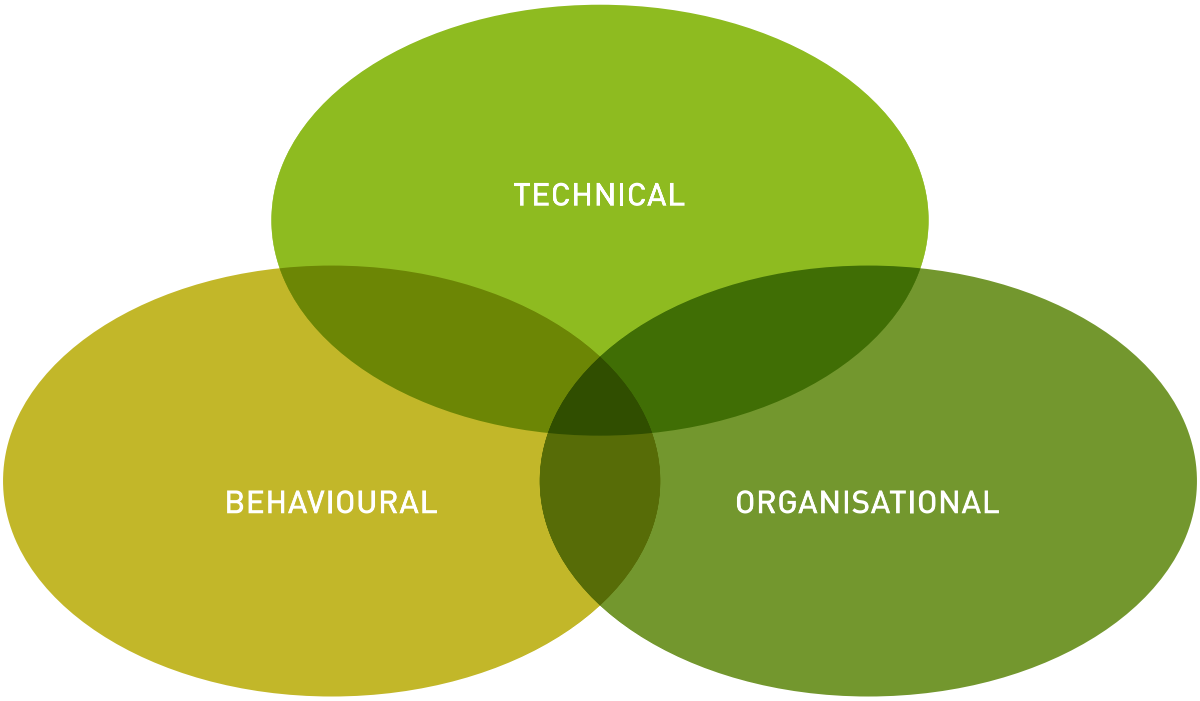

Figure 16 - Dimensions of Energy Management System

ISO 50001 and ISO 50002

ISO 50001/2 is the energy management system norm (a synopsis can be found in Appendix 1 to this chapter). The international norm ISO 50001 specifies the requirements for establishing, implementing, maintaining and improving an **energy management system (EnMS)**, whose purpose is to enable an organisation to follow a systematic approach to continually improve its energy performance, including the aspects of energy efficiency, energy security, energy use and consumption.

ISO 50001/2 is a management system and *not* a guideline on how to reduce the energy consumption of an enterprise, office, hospital, etc. ISO 50001/2 provides neither technical measurements nor standards on how to reduce energy consumption to comply with specific benchmarks. ISO 50001 is a voluntary *management standard* which helps energy users to implement a management system designed to reduce energy consumption and costs.

More detailed information is available at: https://www.iso.org/files/live/sites/isoorg/files/archive/pdf/en/iso_50001_energy_management_systems.pdf

The ISO 50001/2 is the first global standard for EnMS and presents a systematic pathway for implementation. This handbook refers to the ISO 50001/2 almost exclusively. An EnMS encompasses all elements of an organisation that are necessary for creating an energy policy, as well as defining and achieving strategic objectives. It thus includes the organisational and informational structures required for implementing energy management, including all necessary resources. It formulates and implements the energy policy (together with strategic and operational objectives and the action plan), planning, introduction and operation, monitoring and me measurement, control and correction, internal audits, as well as a regular management review.

The ISO 50001/2 standard is a management system which can help to reduce energy consumption and costs, and therefore contribute to sustainability. Energy management and energy efficiency are not just for big companies. Sole trader farmers or small businesses can also achieve sizable savings, because organisations both big and small, all use energy in various ways and there is ALWAYS potential for improvement, i.e. reduced consumption leading to energy efficiency.

The Plan-Do-Act-Check (PDCA) Cycle

The ISO norms 50001/2 is based on the PDCA cycle: plan–do– check–act (or adjust). PDCA is an iterative four-step management method used in enterprises for the control and continual improvement of processes and products. The individual steps of the PDCA cycle in energy management can be described as follows:

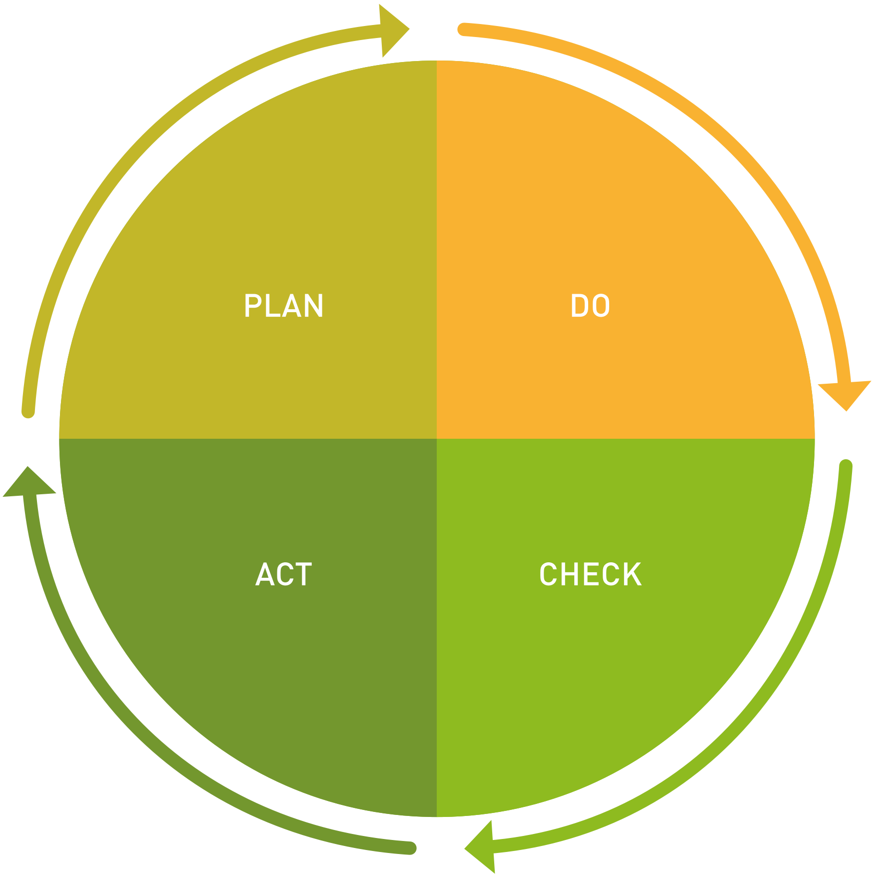

Figure 17 - The Plan-Do-Act-Check (PDCA) Cycle

Plan - Establish the objectives and processes necessary to deliver results in accordance with the expected output (i.e. target or goals). By establishing output expectations, the completeness and accuracy of the specification is also a part of the desired improvement. It is better to begin the planning on a small scale to test possible effects. To summarise: establish the energy-saving targets, determine the strategy, identify measures and responsibilities, provide the necessary resources and prepare an action plan.

Do - Implement the plan, execute the process, and farm, produce or process. Collect data for charting and analysing progress made in the following steps ('CHECK' and 'ACT'). Establish management structures to help maintain process continuity and undertake improvement measures (e.g. more efficient technologies/procedures).

Check - Study the actual results (measured and collected in 'DO' above) and compare them against the expected results (targets or goals from 'PLAN') to ascertain any differences. Look for deviations from the plan and also check the plan's suitability and completeness for execution

('DO'). Charting data can make it much easier to spot trends over several PDCA cycles and convert collected data into information. Information is what you need for the next step ('ACT').

Review the level of target achievement and the effectiveness of the EnMS, collect new ideas by undertaking energy audits. Consider consulting an external expert (also examine and consider deviations as well as corrective and preventive actions).

Act - If the CHECK step shows that the PLAN implemented in DO does in fact improve on the prior standard (baseline), then it should become the new standard (baseline) for how the organisation should ACT going forward (new standards are enACTed). If the CHECK shows that the PLAN implemented in DO does not represent an improvement, then the existing standard (baseline) will remain in place. In either case, if the CHECK turned up an unexpected deviation (whether for the better or the worse), then there is further potential for learning... and that suggests additional **PDCA cycles**. All steps and activities can take place in parallel; the decision to begin a step or an activity depends on the conditions in the respective company.

When compared to selective measures (ad-hoc energy management), continuous application of this process clearly reduces the energy-related costs of an enterprise.

Example: (adapted) EnMS to reduce energy costs.

To implement the EnMS, a continuous, objectively assessable improvement process should be evident in the structures of the enterprise. The manager of the enterprise initiated the process by including the objective of energy-efficient management in the enterprise philosophy, appointing a part-time Energy Manager and providing him/her with the corresponding resources and responsibilities (**Plan**).

The Energy Manager accepted the responsibility for coordinating the documentation of all energy-related processes in the enterprise. "Samoan Banana Packing House" has already adopted other approaches in the hope of implementing an overall environmental management system. In the past, however, these approaches were not applied in a systematic manner, because only certain processes in the enterprise were controlled and directed by the 'system'. Nevertheless, there is some knowledge about management systems in the enterprise. To reflect the continuous improvement process, management establishes a structure to introduce an EnMS that will make it possible to record and assess all energy flows in order to then identify savings potentials and implement measures which are technically viable, financially attractive and within the company's overall means (**Do**).

The Energy Manager regularly assesses the results of the measures, sets new targets and compiles reports.

The Energy Manager then implements newly defined targets and measures with the support of employees and an external energy advisor (**Act**).

1.3.2. Energy efficiency definition

Understanding this concept is highly important for the decision makers of an enterprise during the selection and procurement process for energy intensive equipment as well as for Energy Auditors when calculating or testing the energy efficiency of a machine. Even the software driving EnMS equipment as well as the associated data analysis functions all fundamentally apply the equations and principals behind the concept. Therefore, a brief overview of the various interpretations and financial implications of energy efficiency follows.

1.3.2.1. Energy efficiency and conversion

Energy can be neither created nor destroyed but only converted from one form of energy to another. This conversion is performed by equipment such as boilers, electric motors, pumps, blowers, lights and diesel generators. Equipment responsible for the energy conversion process always produces some unused energy that is lost to the environment (but could be partially recovered) and discharged mostly in form of heat which leads into how best to measure or calculate energy efficiency (Source GIZ 2017). Figure 18 defines the **energy conversion efficiency** or **energy efficiency** or simply **efficiency** of a machine. This mathematical equation that is used by engineers, norms and standards gives it the Greek letter eta (**n**).

$$\eta = \frac{\text{useful energy input}}{\text{energy input}} = \frac{\text{energy input} - \text{losses}}{\text{energy input}} = 1 - \frac{\text{losses}}{\text{energy input}} < 1$$

Figure 18 - Equation energy conversion efficiency

1.3.2.2. Measuring and calculating energy efficiency

The equation (above) demonstrates that there are two methods to determine efficiency:

- The first method is to measure over a given period of time all energy inputs as well as all useful energy outputs. For example, the measurable energy input flow of a steam boiler running on heavy fuel oil, would be the volume of fuel oil multiplied by its energy content. The useful energy output is the measured volume flow of live steam multiplied by its energy content leaving the boiler.
- The second method, often called the indirect method, is usually more preferable since it allows losses to be identified and quantified. The lower the energy loss of a machine or a process, the less input energy is needed to manufacture a product or deliver a service.

Far more detail on how to calculate energy efficiency relevant to agro-food chains is detailed in Chapter 2.

The table below provides some examples of **Energy Efficiencies** and **Corresponding Technical** Losses of various technologies.

Table 7: Examples of Energy Efficiencies and Corresponding Technical Losses of various technologies

Technology	% Efficiency	% Losses
Step-up transformer of a power plant	98	2
Condensing fired hot water boiler	96	4
Electric motor	92	8
Non-condensing oil-fired boiler	87	13
Combined heat and power plant	80	20
Pumped storage power plant	72	28
Combined cycle gas turbine (CCGT)	60	40
Supercritical coal-fired power plant 1,000MW block	44	56
Larger heavy fuel oil generator set	40	60
Open cycle gas turbine (OCGT)	34	66
High efficiency photovoltaic cell	28	72
Biomass power plant	26	74
LED Light	16	84
Small 2-5 kW gasoline captive power back-up	13	87
Incandescent light bulb	4	96

Source: Adapted from Energy Management Course Handbook
for a 160-hours training course for engineers 2nd Edition • May 2017

1.3.3. Energy savings

Definitions

Quite a number of countries have introduced incentives for consumers who 'save energy'. The initiatives are mostly managed by energy utilities and take the form of rebates for buying energy-efficient white goods or lighting to reduce monthly electricity bills or for investing in other energy management opportunities (EMOs) to reduce natural gas and electricity consumption. Incentives for energy savings are a key component of North-REP (North Pacific ACP Renewable Energy and Energy Efficient Project) Palau – more information available at: http://prdrse4all.spc.int/system/files/north-rep_palau_brochure.pdf

In the context of this training manual the following definitions are applied as they fit within the context of energy savings:

a. **'Energy efficiency savings'** means the saving of energy by increasing the energy efficiency of a technology or process either by retrofitting or by procuring more efficient equipment.

Example 1: Incandescent light bulbs are replaced by efficient LED lighting for an energy efficiency savings of 75%.

Example 2: An open cycle gas turbine (OCGT) is converted to a combined cycle gas turbine (CCGT). The measure will increase the design energy efficiency from 32% to 50%, resulting on paper in an energy efficiency savings in the form of natural gas of (50–32)/50 = 36%.

b. **'Energy conservation'** means the saving of energy **without** increasing the energy efficiency of a technology or a process.

Example 3: Turning off office lights at night when not needed is a typical energy conservation measure that does not improve the energy efficiency of a lighting system.

Example 4: Increasing the temperature of an air- conditioned room from 22 °C to 24 °C will reduce the electricity consumption of the air conditioner but not improve the design energy efficiency of an air conditioner.

c. **'Energy savings'** means the saving of energy through energy efficiency savings, or energy conservation, or both.

Example 5: Turning off incandescent lights at night when not needed is an energy saving measure because it conserves energy. Replacing incandescent light bulbs by LEDs is also an energy savings measure because it improves the energy efficiency of the lighting systems and therefore generates energy efficiency savings. Replacing incandescent light bulbs by LEDs and turning the LEDs off at night when not needed is an energy saving measure as well because it improves the energy efficiency of the lighting system **and** on top of that conserves energy.

Calculating energy efficiency savings

A major objective of an Energy Audit (EA) – explained in the next Section - is to find ways to reduce costly energy losses or in other words increase the efficiency of a process or a machine by either retrofitting the technology, or changing the way it is operated, or replacing it by a more efficient and newer design that can perform the same job and provide the same service level as the old one under the same conditions. Energy Auditors have an astoundingly simple way to calculate energy savings based on the energy efficiency concept. This is easily achieved by applying the simple equation below:

$$S = 100 \times \frac{\eta_2 - \eta_1}{\eta_2}$$

Figure 19 - Energy efficiency equation

η_1 = The device with the **lower** efficiency as operated in %

η_2 = The device with the **higher** efficiency as operated in %

S = Energy savings expressed in %

Example 6: An incandescent light bulb is replaced with an LED light with the same lumens per watt of useful energy output. The LED has an efficiency of 16% while the light bulb has only 4%. Consequently, the electricity savings are S = 100* (16–4)/16 = 75% for the same level of lighting services.

Example 7*:* Instead of buying an electric motor with an advertised 83% design efficiency at nominal load management, an electric motor with 87% efficiency is purchased. The electricity cost savings on paper are S = (87–83)/87 = 4.6%.

Energy units: The most common energy units are kWh, kCal, MJ, and BTU.

Energy consumption is measured in joules (J, kJ, MJ, GJ). Another unit commonly used is kWh: 1 kWh equals 3600 kJ. The energy consumption in kilowatt-hour (kWh) can also be calculated using the following equation: kWh= kW (Power generally appears on the name plate of an equipment) X h (number of hours the equipment is in operation).

Energy sources, such as fuels, are also stated in kilograms (kg), standard cubic metres (scm) or litres (l). The table below presents the conversion factors for the common units:

Table 8: Conversion factors for the common units

Energy Source	Unit	Conversion factor[2] in kWh
Electricity	kWh	1
Heating Oil	Litre	9,95
Natural Gas	m^3	9,88
Compressed Gas	kg	12,44
Liquified Gas	Litre	12,9
Diesel	Litre	9,9
Petrol	Litre	8,85
Renewable Energy	kWh	1
District Heat	kWh	1
Wood	kg[2]	4,5

A basic energy units conversion chart, formulas and properties on BTU and other measuring units is in the Appendix 2 of this chapter.

Remember: all EMOs that might lead to energy savings must be technically viable and financially attractive. In other words, a small landholder or an SME must be able to find the way to fund any changes required by the implementation of an EMO.

1.4. ENERGY AUDIT

1.4.1. Introduction

An energy audit (or energy review) is a study of how energy is used in a facility and an analysis of what alternatives could be used to reduce energy costs.

Types of energy reviews

- **Walk-through audit** is the least costly and identify preliminary energy savings. A visual inspection of the facility is made to determine maintenance and operation energy saving opportunities plus data collection of information to determine the need for a more detailed analysis.

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[2] Source: Gemis Datenbank 4.81 (2013).

TEN STEPS TO PERFORMING A WALK THROUGH ENERGY AUDIT

1. Establish existing energy consumption of farm, processing plant, barns for livestock, etc.
2. Using the last 12 months of utility bills, establish the monthly kWh hours and divide them by the amount of the bill. Total all of the monthly kWh hours and divide by 12 to obtain average monthly kWh hours. This step provides the 'real cost' of kWh as many other costs such as taxes, charges for peak loads, maintenance of equipment or infrastructure costs, provisions for new infrastructure, etc. care factored into monthly utility bills.
3. Determine the number of hours when all equipment is operational. There are 8760 hours in a calendar year. Calculate the annual operational hours for each type of equipment or area.
4. If possible, obtain a copy of the plans for each area where equipment is operational or for example a barn that houses livestock. This helps to establish the dimensions of an area for example being heated or ventilated. Confirm the wattage and quantity of each type of equipment.
5. Use the appropriate type of meter to take readings. If there is poor uniformity between pieces of similar equipment note the highest and lowest readings of consumption. Note any great extremes.
6. Observe fixture types, where equipment is positioned, in fact anything that affects the optimum operation of a particular piece of equipment.
7. Identify ways in which equipment, arrangement of equipment, the usage during peak times, use during periods of low consumption etc. can contribute to reductions in average kWhs.
8. If possible, use a basic software program to assist with calculations for energy savings. The basic formula for energy savings is

$$\frac{\text{Watts Saved X Hours Used X kWh Rate}}{1\,000}$$

An example of this would be taking the energy saved by retrofitting 100 metal halide 400 watt fixtures (458 watts including ballast consumption) with 218 watt

6-lamp T8 fluorescent fixtures. The savings is 240 watts per fixture for a total of

24000 (240 X 100 fixtures). If they are on an average of 12 hours a day for 360 days a year the annual burning hours would be 4320. Assuming .10 kWh the calculation would be

$$\frac{24000\text{Watts X }4320\text{Hours X }.10\text{ kWh Rate}}{1\,000} = \$10,368.00\text{ annual savings}$$

Software programs can extend this to reflect 5 or 10 years of savings to create an even more impressive long term savings.

Consider other ways to reduce energy consumption.

Investigate if there are other ways in which energy savings can be made or if there are other more attractive usage plans offered by the energy supplier/utility company i.e. peak equipment usage in off-peak consumption periods, etc.

- **Comprehensive audit.** This type of audit requires tests and measurements to quantify energy uses and losses and determine the economics for changes and further evaluate how much energy is used for each function such as lighting, process, etc.

Generally speaking, an audit or review follows the process outlined below:

AUDIT PROCESS

Main objective: Identify opportunities to reduce energy consumption and cost.

Equally important: Provide to owner/operator to decide which recommendations to implement

Typical steps:

PRE- AUDIT

- Collect/ analyse historical energy use data
- Study building and operating trends

AUDIT

- Collect building information and consult with staff / occupants
- Identify potential modifications to reduce energy and cost

POST-AUDIT

- Preform engineering and economic analyses
- Prepare a prioritized list of recommendations
- Report results

Source: Reproduced from USA Department of Energy, DOE's State and Local Technical Assistance Program, May 23, 2013 available at: www.eere.energy.gov

1.4.2. Pre-audit

The pre-audit can be broken down further to the following steps:

1. Plan – develop a pre-assessment questionnaire to obtain basic energy data and information on process flow, equipment list and plant size, type, year built, O & M schedule, locations, occupancy rate, building envelope, etc.

Measurement plan:

- Identify measurement devices already in use;
- List them according to each area to be included in the audit;
- Identify measurements that need to be taken in the audit;
- Develop a plan for a future monitoring landscape of the farm/enterprise.

2. Define responsibilities and deadlines for the audit/review.
3. If appropriate, organise a meeting to establish the objectives and targets of the audit/review.
4. Define the scope and boundaries and segment each boundary according to significant energy use, production line, or distribution network in order to manage them in a more focused way and to have best control over their performance.

Flow Meter

Lux meter

Multi-meter

Digital Infra-Red Thermometer

Figure 20 - Some of the Energy measuring equipment

5. Obtain and evaluate **historical energy/production data**, to establish **energy baseline.**

Table 9: Historical energy/production data table

From name plate

Measurement or estimation

From counter or estimation

Use	Rated Power (kW)	Average load factor (%)[3]	Hours/Day	Days/Years	Hours/Year	Consumption (kWh/a)	Share of Total
Electricity uses							
Compressed Air	100	60%	14	250	3,500	210,000	4.20%
Ventilation & Air Conditioning	50	40%	14	250	3,500	70,000	1.40%
Refrigeration		70%			0	0	0.00%
IT & Servers	2	50%	24	365	8,760	8,760	0.18%
Lighting	20	100%	14	250	3,500	70,000	1.40%
Workstations	1	30%	10	250	2,500	750	0.02%
Machines	390	70%	14	250	3,500	955,500	19.11%
Kitchen/Canteen		80%			0	0	

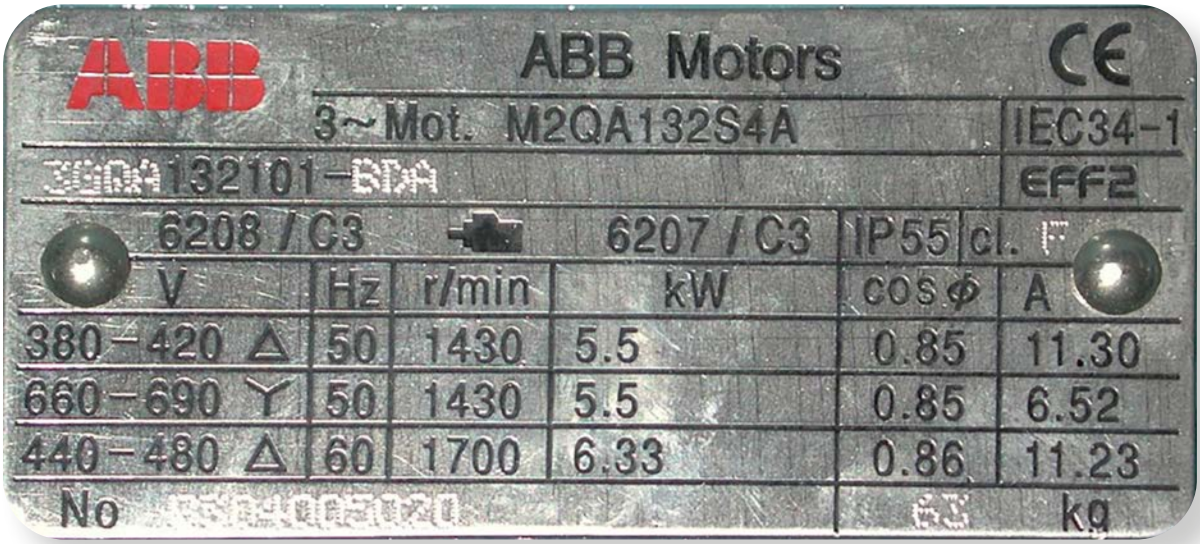

Figure 21 - Basic energy data and information from equipment name plat

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[3] The average load factor, is either a standard values from the equipment manufacturer which can be found in the equipment manual or an expert can provide this information.

1.4.3. Audit

Conduct site visits – take inventory of facility and energy production and consuming equipment i.e. generators, transformer, compress air system, furnace, boiler, air handling units (AHU), motors, plug loads, etc. specific to each boundary identified and type of control system in place.

- Identify significant energy uses (SEU) according to the boundaries and carry out real time measurement and data logging.
- Interview key staff about influencing factors, awareness, work routines, etc.
- Identify energy efficiency measures (EEM) and efficiency of each major energy consuming systems (SEUs).

Major systems to consider:

- **Lighting –** making a detailed inventory of all lighting is important. The inventory should include type of light fixtures and lamps, wattage of lamps and hours of operation. Be sure to take notes of the tasks performed in each area. This will help the auditor to select alternative lighting technologies that might be more energy efficient.
- **HVAC equipment** – all heating, air conditioning and ventilation equipment should be noted on the inventory. Size, model numbers, electrical specifications and estimated hours of operation. Also, inspections of the system efficiency need to be conducted on a regular basis.
- **Electric motors –** an inventory of defined electric motors size range taken. Motor size, use, age, model, estimated hours of operation, electrical characteristics, and, possible integration of variable speed drive need to be detailed.
- **Peak equipment load –** look for any piece of electrically powered equipment that is used infrequently or identify how the use could be controlled or shifted to off-peak times
- **Waste heat sources –** identify possible opportunities of waste heat recovery usually from system exhaust to be used for pre-heat or total source needed for hot water
- **Steam/compressed air systems –** inspect steam pipe lines in order to identify any leaks or insulation breakdowns.

1.4.4. Post-audit

1.4.4.1. Analysis

Conduct a detailed analysis of measured parameters to obtain the efficiency of the system, energy rations, areas of significant energy usage and areas for potential energy savings.

Far more detail on how to calculate energy savings relevant to agro-food chains is detailed in Chapter 2.

1.4.4.2. Reporting

The audit findings should be summarised in a concise and practical way so that the decision- maker (farmer, owner of the enterprise) is able to rely on the information gathered during the audit/review to identify what actions are necessary to improve energy efficiency and the financial costs involved.

Explain the assumptions made and the measurements taken. Indicate how the farmer/enterprise can improve its energy performance **continuously** (i.e. include a monitoring program, improved awareness, more effective management, etc.). The length and detail of the report will vary depending on the type of the facility under audit/review. An industrial audit should include a detailed explanation of the EMOs and cost-benefit analysis.

More detailed information is available at: http://www.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/files/pdf/energy-audit-manual-and-tool.pdf

1.5. SUMMARY

The material presented in this chapter has focused on the challenges related to the agriculture/climate change/energy nexus.

Some of the lessons learned can best summarised as:

- The impact of climate change and burgeoning populations have serious impacts for food security.
- To ensure food security agricultural output will have to increase by around 60% up to 2050.
- Agro-food chains account for around 30% of global energy consumption, with 70% consumed beyond the farm gate which in turn produces 1/5th of global GHGs.
- In 2015 most of the countries of the world signed up to the Paris Agreement which seeks to contain global temperatures to less than a 2°C increase through increased energy efficiency and a lowering of GHG emissions.
- The integration of RE into energy systems provides for lower GHG emissions which bring **triple wins** and **co-benefits** at all points along agro-food chains.
- **Climate smart agriculture** and **energy-smart-food systems** provide the way forward for agro-food chains.
- The UN's **SE4ALL** program supports nations to revise their energy policies to include a switch from fossil fuels to RE.

Farmers from small landholders up to commercially operated farms, as well as the processing, packaging and marketing industries along agro-food chains can improve **energy savings** leading to greater **energy efficiency** and reduced **energy costs** at all levels of their operations by having knowledge about the basic economic tools and management systems used for this purpose:

- **Cost-benefit analysis, life cycle cost assessment** and **life cycle assessment** provide the means with which to determine the benefits of an investment, identify operational costs over the long time and to identify the environmental footprint of major investments in large energy projects.
- **Energy management systems** – if implemented properly – help to identify where energy savings can be made which in turn leads to improved energy efficiency and financial benefits for farmers or enterprises.
- **Energy audits or energy reviews** if undertaken on a regular basis help to identify the energy consumption items in an energy system where changes need to be made in order to reduce energy costs.

1.6. APPENDIXES

A1: ISO 5000-1 – Energy management systems

ISO 50001

ISO 50001

Energy management
systems

A2: Energy units conversion chart, formulas and properties

Procedures for Commercial Building Energy Audits, Second Edition/ Energy Units—kBtu Conversions

Multiply the baseline quantity by the conversion multiplier to obtain a result in kBtu.

Fuel	Measured Units	Conversion Multiplier	Source
Any	MMBtu	1000	
	therms	100	
	dekatherms	1000	
Electricity	kWh	3.412142	
	MWh	3412.142	
Natural Gas	ft^3	1.027	
	CCF (100 x ft^3)	102.7	2
	MCF (1000 x ft^3)	1027	2
	therm	100	2
	m^3	36.4	
	MJ	0.9478171	
	GJ	947.8171	
Purchased Steam	1000 Btu	1	
	1000 lb (approx)	970	
	lb (steam, 15 psig, evap)	0.945684	3
	lb (steam, 50 psig, evap)	0.912061	3
	therm	100	
Purchased Hot Water	1000 Btu	1	
Purchased Chilled Water	1000 Btu	1	
	ton-hour	12	
Oil #1	U.S. gallon	137.4	1
Oil #2	U.S. gallon	139.6	1
	Imperial gallon	167	
	litre	36.7	
Oil #3	U.S. gallon	141.8	1
Oil #4	U.S. gallon	145.1	1
Oil #5	U.S. gallon	148.8	1

Oil #6	U.S. gallon	152.4	1
	Imperial gallon	185	
	litre	40.7	
Diesel	U.S. gallon	139	5
Gasoline	U.S. gallon	124	6
Propane	U.S. gallon	91.33	2
	cubic feet	2.55	2
	Imperial gallon	110	
	litre	24.2	
Anthracite Coal	ton	25 400	
	short ton (coal)	19 953	4

Sources

1 2009 ASHRAE Handbook—Fundamentals, Table 6, page 28.7

2 2009 ASHRAE Handbook—Fundamentals, page 28.5

3 2009 ASHRAE Handbook—Fundamentals, Refrigerant-718 (steam) table, page 30.37 (note this is heat of vaporization only)

4 ASTM Standard D388

5 ASTM Standard D975

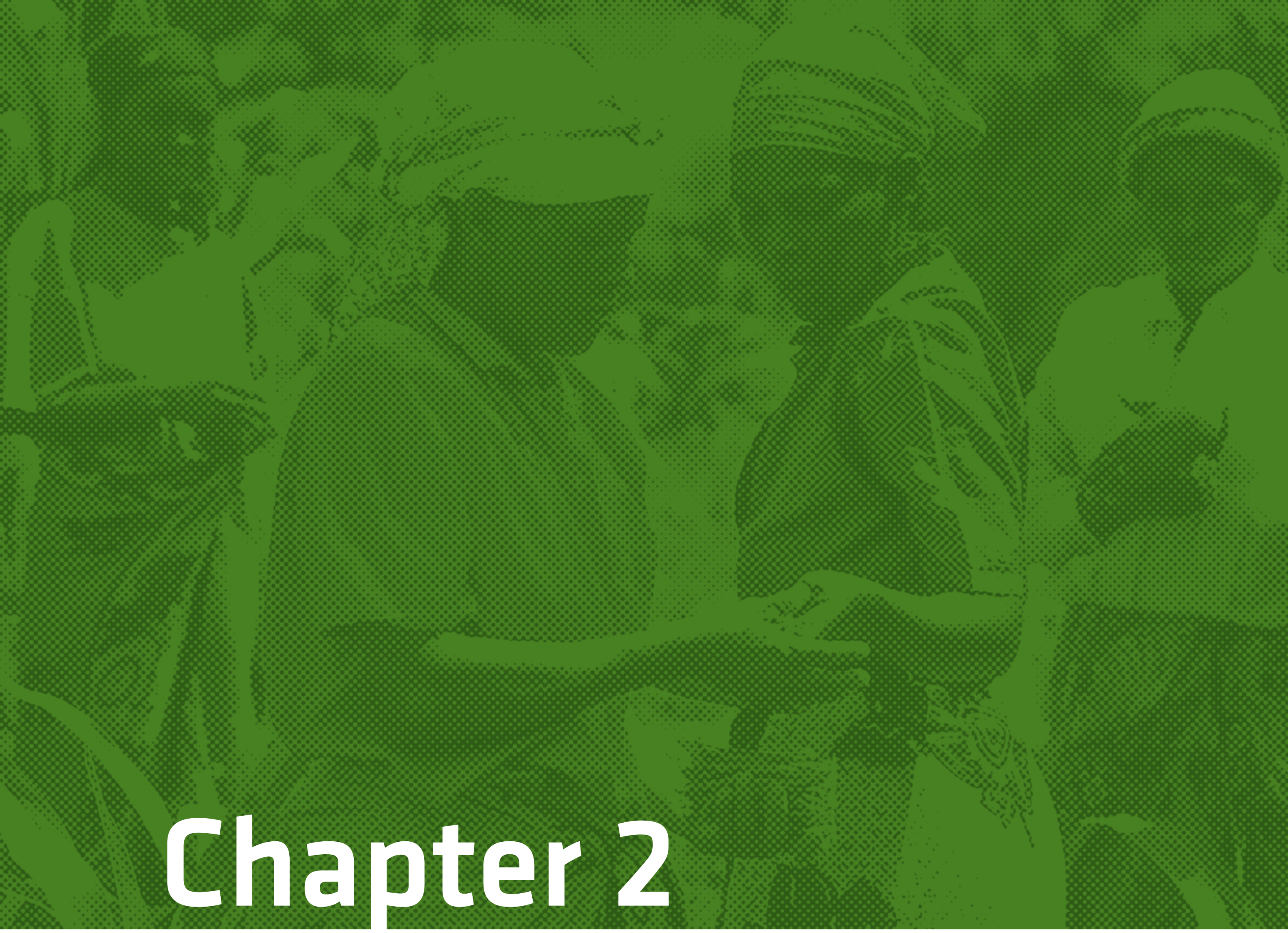
6 ASTM Standard D4814

Procedures for Commercial Building Energy Audits, Second Edition
Formulas and Properties

Formulas		Notes
Sensible Air Conditioning	Btu/h = 1.08 * ΔT * cfm	
Latent Air Conditioning	Btu/h = 4.5 * cfm * ΔH	
Water Heating/Cooling	Btu/h = 500 * gpm * ΔT	
	"Btu/h = gpm * ΔT * 8.34 Btu/gal-ΔT	Derivation
	* 60 min/h * 1 kW/1000"	
	tons = gpm * ΔT/24	
Water hp	= ft head * gpm/3960	
Pump Motor hp	= water hp/(pump eff * motor eff)	
Pump Hydraulic hp	= gpm * (ft H_2O)/3960	
Fan Motor hp	= cfm * SP/(6354 * Motor Eff * Fan Eff)	6354 cfm * in. H_2O/hp
kW	= 0.746 * hp * (Load Factor)/(Motor Eff)	
EER	= (Btu/h of Cooling Delivered)/ (W Input)	
	= (kBtu of Cooling Delivered)/ (kWh Input)	
HSPF	= (kBtu of Heating Delivered)/ (kWh Input)	Seasonal Avg
COP	= EER/3.412	
	= 3.516/(kW/ton)	
	= 1/EIR	
kW/ton	= 12/EER	
EIR	= 1/COP	
	= (kW/ton)/3.516	

Other miscellaneous unit equivalents	
1 hp	0.7457 kW
1 ton	12,000 Btu/h
1 lb H_2O	7000 gr
1 psi	2.307 ft H_2O
1 U.S. gallon	0.1337 ft^3
1 Imperial gallon	0.1605 ft^3
1 ft^3 H_2O	62.4 lbm H_2O

Material	Properties	
Steam	Enthalpy of Vaporization	970 Btu/lb
Water	Density	8.34 lbm/gallon
	Specific Heat	1 Btu/(lbm-°F)
Propane	Heat of Combustion	2500 Btu/ft^3
	Heat of Combustion	21,560 Btu/lb
Natural Gas	Heat of Combustion	1000 Btu/ft^3
Wood	Heat of Combustion	8000 Btu/lb
	Density	45 lb/ft^3



Chapter 2

Effective use of energy, paths to rationalisation, energy balance

LEARNING OBJECTIVES

At the end of this chapter, the learner should be able to:

- Identify positions where reduction in consumption is possible.
- Understand how to limit energy consumption in a farm/ company.
- Understand how to undertake an Energy Balance.
- Quantify **inputs and outputs at the farm level.**

2.1. ACCESS TO ENERGY

Agriculture is one of the most innovative and energy intensive industrial sectors worldwide thus contributing significantly to global energy consumption along the various points of agro-food chains. However, the agricultural sector is a sector where tight profit margins can make and break businesses. Thus, farmers and enterprises need to be open to new ideas if a farm is to survive and thrive in modern times. Agricultural enterprises use energy both directly in the form of fuel (gasoline, diesel, natural gas) and electricity and, indirectly through use of energy-intensive inputs, such as fertilizers and pesticides. As energy is at the heart of every farming operation, it is vital for farmers and enterprises to embrace new ideas which are targeted at using energy in an efficient way. And, like any modern business, the farmer or enterprise can thus benefit from this concept by cutting operating costs, minimizing risks, or even generate additional income by selling the on-site-energy surplus.

Efficient energy use benefits not only the global community in the form of co-benefits and food security; efficiency in energy usage can also impede or support regional development plans and ultimately make or break agricultural communities. However, the present reality is that most small landholders and enterprises in many of the ACP countries sometimes have limited access to energy or volatile prices and availability impact on the overall sustainability of an agro-food chain operation. At the time of writing the situation with access to energy can best be described as follows:

Caribbean – CARICOM Member States are mostly importers of fossil fuels. The fifteen Member States can be classified into the following broader groups based on the import and export capabilities of petroleum derived products:

- Hydrocarbon producers: Trinidad and Tobago are the only net energy exporters of petroleum related products and natural gas within the region.
- Other energy producers: Suriname, Barbados and Belize produce crude oil that supply only some of the domestic needs so these countries are still considered to be overall as importers.
- Non-hydrocarbon producers: all other CARICOM States do not produce hydrocarbons so they are net importers.

Overall, the CARICOM member states are not major players in the global markets and therefore hostages to the vagaries of international supply and pricing of fossil fuels. This region faces some challenges although it does benefit from some distinct opportunities. The challenges relate to the weak security of energy supplies in the Region, energy poverty at various levels and an urgent need to lower the regional carbon footprint in order to increase climate compatibility of the energy sector. Despite the affordability of energy, the relatively low competitiveness of the majority of the CARICOM economies are affected by high and unpredictable cost of imported fuels. Opportunities can be found in greater RE penetration within the power sector (Gardner, 2017).

Pacific Region - the majority of the Pacific Small Island Developing States (PSIDS) depend almost exclusively on imported refined oil products to meet their power generation and transportation energy needs with most of the islands located far from major oil refining and distribution hubs and depending on complex and lengthy fuel supply chains. Fuel delivery logistics are often further complicated by lack of modern port facilities in some islands, requiring the use of smaller, specialised ships. Although the fuel demand of individual islands is small, both geographic size and economic resources of islands constrain fuel storage. These factors reduce the purchasing power for oil. At the time of writing the PSIDS face some of the world's highest fuel costs and have greater exposure to price volatility and supply disruptions (Mofor *et al*., 2013).

The African Continent - on a region by region basis the African ACP nations do have local mainly fossil fuel supplies that are traded on an intra-regional basis. However, despite the abundance of fossil fuel supply in some regions, many countries are still net importers of energy. Consequently, many enterprises along the various agro-food chains have limited access to a reliable electricity supply. This situation is also exacerbated by the fact that many of the African ACP countries are some of the most energy poor nations of the world as detailed in Figure 1 below.

Access to energy in different parts of the world (from 1990 to 2010)

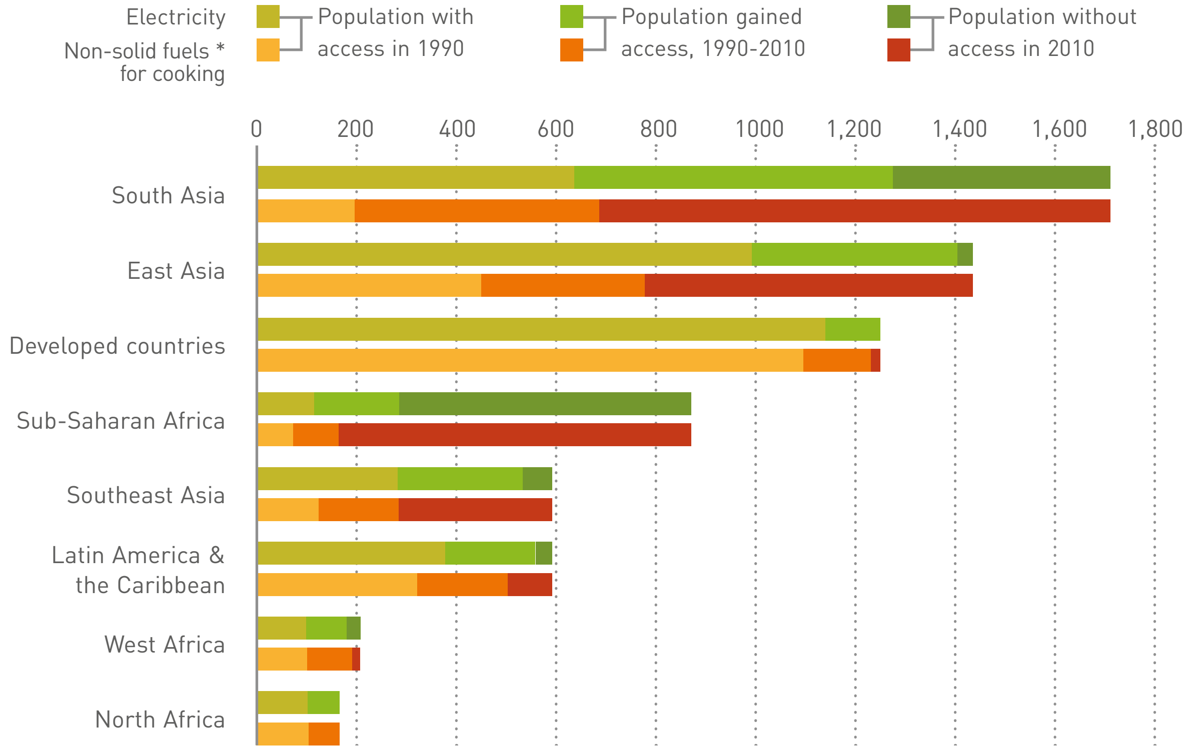


Figure 1 - Access to energy by region
Source: SE4ALL, Global Tracking Framework Report
* Including kerosene, ethanol, natural gas and electricity
Economist.com/graphicdetail

According to the IEA, 634 million people did not have access to electricity in 2014. In 2014 the continent's overall electrification rate was at 45%, of which 72% was in urban areas and rural areas accounted for only 28%.

Presently, the situation across the ACP countries can be summarised as follows:

- West Africa: which includes Benin, Burkina Faso, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo. Nearly all of the regional capacity comes from Nigeria, Ghana and Cote d'Ivoire. Some of this grid-connected capacity uses natural gas in thermal power plants, a small amount is sourced from hydropower and the remainder from mostly oil. Electricity trading in the region accounts for a small percentage of gross demand. Benin, Niger, and Togo rely almost entirely on imports to meet demand.
- Southern Africa: which includes Botswana, Lesotho, Namibia, South Africa, Swaziland, Coal is the main energy source in Botswana and South Africa. The rest of the region relies predominantly on hydropower. Only small amounts of the electricity generated in the region is traded within the region, with smaller countries reliant on imports.
- East Africa: which includes Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Somalia, Tanzania, Uganda, Zambia and Zimbabwe. At the time of writing Egypt accounts for most of the installed capacity in the

region. Natural gas is the primary feedstock in Tanzania. In Burundi, Ethiopia, and Uganda, hydropower is the main source. After gas and hydro, remaining capacity is mainly based on oil-fired power plants, with small contributions from wind and solar. Electricity trade within the region is low but imports from DRC are important for dependent countries such as Burundi and Rwanda.

- Middle Africa: which includes the following countries: Angola, Cameroon, Central African Republic, Chad, Republic of the Congo (Congo), DRC, Equatorial Guinea and Gabon. At the time of writing approximately 75% of total installed capacity comes from hydropower, with most of the rest from thermal plants. The government of Angola projects that by the end of 2018, the country's power generation mix will consist of 64 percent hydropower, 12 percent natural gas and 24 percent other fossil fuels, according to the U.S. Department of Commerce. Chad, Equatorial Guinea and Gabon use mostly oil, whereas Congo complements its hydropower with gas-fired thermal plants. Imports meet just 4% of demand in the region but are concentrated: import dependency is particularly high in some smaller countries (Miketa & Saadi, 2015).

2.2. ENERGY EFFICIENCY

On a global scale, the exponential increase in energy consumption by the agricultural sector has left most farmers and other actors in the agricultural sector vulnerable to high energy costs and volatile market fluctuations. Yet, if implemented effectively, energy efficiency measures can help agricultural producers decrease the amount of energy they use without harming productivity and at the same time reducing their energy related costs. This will enable them to be less vulnerable and to contribute to more local economies. In fact, there are many opportunities for direct energy savings in agriculture enterprises by integrating RE technologies into energy systems. This integration take place in many different operational areas including high efficiency ventilation systems, variable speed drives, high efficiency compressors, heat recovery systems, pre-coolers, high efficiency lighting, and high efficiency heating systems, to name just a few.

A fine but simple example of how energy efficiency and energy savings in irrigation can be found in Kenya. Here solar-powered irrigation kits combine cost-efficient solar pumping technology with high-efficiency drip irrigation systems achieving yield increases of up to 300% and water savings of up to 80%. It also pilots a pay-as-you- go to make technology more affordable for small landholders because there is no up-front investment in the infrastructure on the part of user. Another very relevant example of what can happen beyond the farm gate can be found in Tanzania where Tanzania East Africa Fruit Farm and Company buys fruit and vegetables from small landholders and larger enterprises and processes them with green energy solutions. It also applies solar power and bio-diesel in irrigation and greenhouses, cooling and transportation (SEED, available at www.seed.uno).

Another fine example in the Box below relates how the replacement of fossil fuels with the use of Jatropha Oil as a RE fuel source to provide electricity and shaft-power in Mali has effectively provided women involved in farming with increased productivity and incomes from the cultivation of crops sold at local markets. These new energy efficient practices have also freed up between 2 and 6 hours a day that women can devote to other activities such as pursuing an education. Traditionally they harvested the Jatropha seed to produce medical treatments and soap. The technological switch is a simple one based on the use of Jatropha Oil in place of fossil fuels and a multi-function platform that can be deployed for various farming tasks (USAid, 2009).

The technology combines local production from non-edible vegetable oil from Jatropha curcas with a muti-function platform (MFP)

The MFP integrates a small 10HP Lister diesel engine, retrofitted to use vegetable oil with a battery charger, grain grinder, oil expeller and generator (7.5 kVA) that supplies local evening electricity

Each piece of specialized equipment is belt-driven from the engine. The belts can be changed easily depending on the desired function

Other functions of the MFP include a compressor and electricity supply for powering tools and welders for workshops

Energy efficiency gains can be made in agro-food chains by decreasing energy input and use, as well as by reducing energy losses.

Other opportunities for indirect energy savings can be found in the form of organic farms, which use much less fossil-fuel energy than their conventional counterparts. Also, the use of organic fertilizers can be chosen as an energy efficiency measure to help balance inputs and outputs from nitrogen, phosphorus and potassium in soil content. Organic farms provide triple wins for enterprises and agricultural communities in the better nutritional quality of produce, lower pollution of water tables, help to minimise water uptake (as the result of tillage and mulching) and maintain water quality. Organic farming makes contributions to biodiversity, minimal pest residues and less worker exposure to pesticides, lower total operational costs and higher profitability as detailed in Figure 2 (UCS Science Network, 2016).

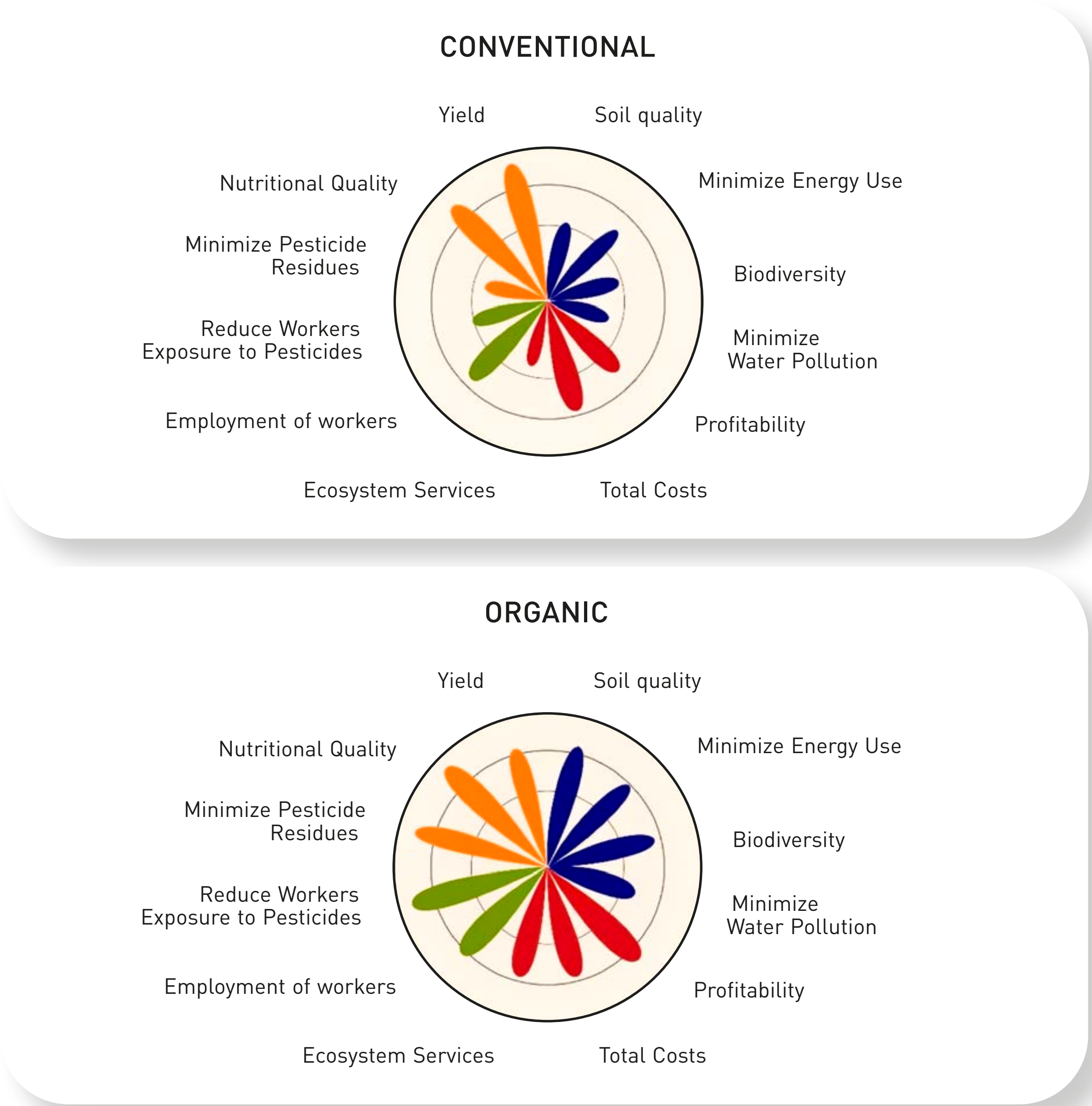


Figure 2 - An assessment of organic farming relative to conventional farming illustrates that organic systems better balance the four areas of sustainability: production (orange), environment (blue), economics (red), and social wellbeing (green).
Source: Organic Agriculture Is Key to Helping Feed the World Sustainably, 2016 available at http://blog.ucsusa.org/science-blogger/organic-agriculture-is-key-to-helping-feed-the-world-sustainably

To be able to identify ways to limit energy consumption on a **farm/ company a flow chart of the production process should be prepared.** At each step of the production process the energy service demand needs to be determined e.g. the energy demand is a solar driven water pump for greenhouse farming, using gravity supply where possible and using efficient water pump designs (correctly matched to suit the tasks) are some of energy efficiency technologies/ measures that can be implemented as outlined in Figure 3 below.

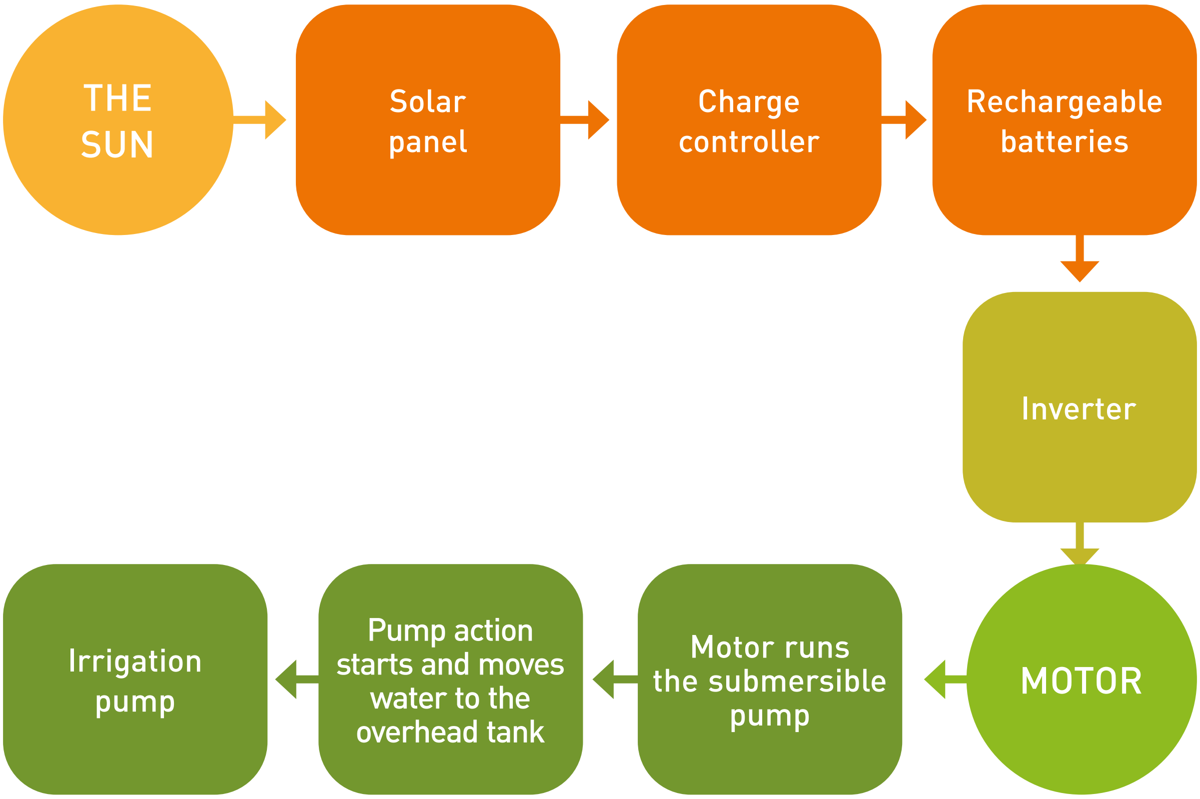


Figure 3 - Block diagram of automatic solar submersible pump control for irrigation
Source: http://salembenmoussa.blogspot.com/2016/03/automatic-solar-submersible-pump.html

Finally, options for financing alternative energy solutions that lead to improved energy efficiency are very much dependent on the regulatory, environmental, economic and social context in which the farm or enterprise is placed. Alternative energy technology options will need to be adapted to local conditions. That is, regulatory bodies will need to provide the 'ecosystem' in which these alternative energy solutions can both emerge and survive over the long-term. This means each 'ecosystem' requires a series of sound building blocks as detailed in the diagram below as reproduced from IRENA.

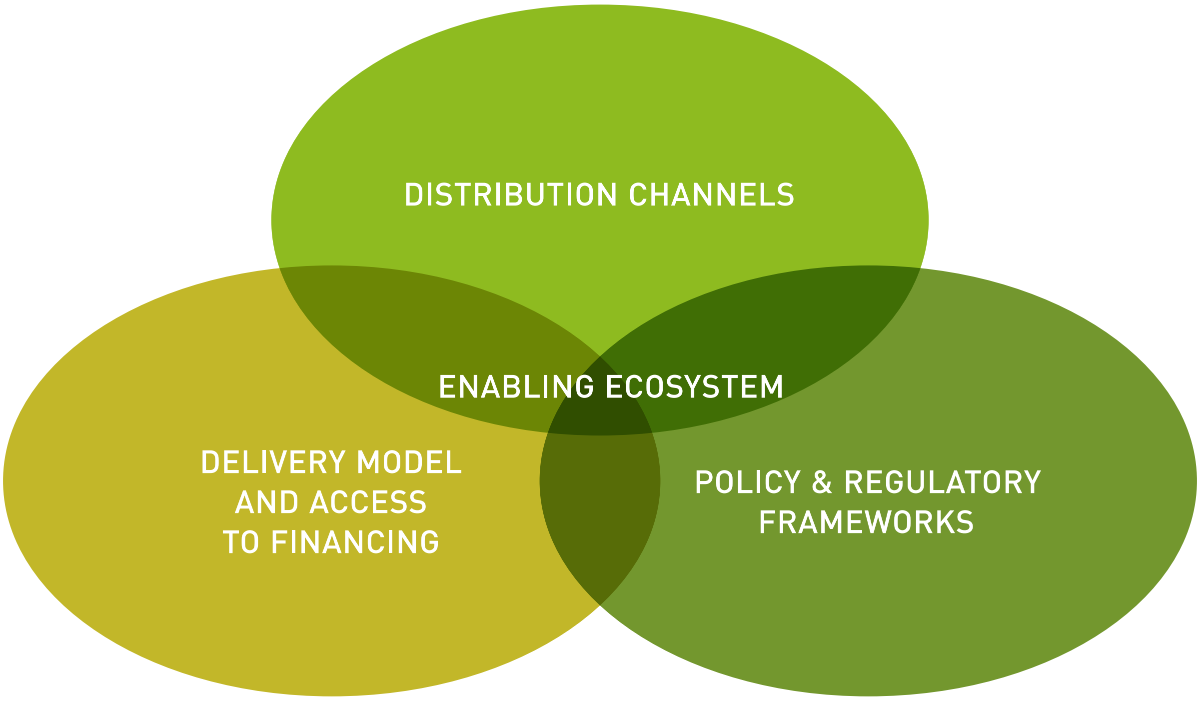


Figure 4 - Building blocks of an ecosystem to support alternative energy solutions
Reproduced from: Solar pumping for irrigation: Improving Livelihoods and Sustainability – IRENA, June 2016

Some of the more detailed issues that farmers and enterprises need to take into account during the decision-making process are: the nature and size of the investment required, operational cost analysis, available financing, cost-benefit issues, the availability of local skilled labour, the capacity for local maintenance, and how all of these issues fit with national, regional and local policy requirements.

- Many ACP countries are net energy importers.
- Volatile prices and insecure supply affect production and processing costs along the agro-food chains in ACP countries.
- Efficiency in energy use leads to higher profits for enterprises and increases in living standards in agricultural communities.
- Energy efficiency gains can be made in agro-food chains by decreasing direct and indirect energy input and use, as well as by reducing energy losses.

2.2.1. Direct and indirect energy inputs

Processing, post-harvest, storage and cooling are considered to be energy-intense steps of agro-food chains that rely on conventional fossil fuel derived energy. All of these activities in food production systems are necessary to process raw food products into consumer products for local, national and export markets. These activities require both direct and indirect energy inputs.

1. Direct energy inputs take the form of: petroleum fuels for tractors, harvesters, trucks and irrigation plants; electricity for motor drives, lighting, refrigeration, water pumping; and natural gas for water heating, steam raising, and process heat.
2. Indirect energy inputs include those used for the manufacture and delivery of fertilizers and agro-chemicals. Indirect energy inputs are also taken up in farm buildings and processing factories, machinery and equipment, as well as for transport, food retailing and cooking.

Yet, for non-industrialized agro-food chains, increased energy inputs can lead to greater food security and improved livelihoods for the rural poor as previously discussed in Chapter 1. These behind the farm gate producers mostly rely on the cultivation and sale of horticultural products for their livelihoods. Fruit and vegetable produce needs to be handled gently to ensure that it is not damaged prior to hitting markets. Therefore, it is essential to protect the quality and extend their shelf life. Manual and animal-powered activities are often used, and in many cases manual harvesting remains the preferred method for this type of delicate high-value products.

Some of the energy requirements for the agro-food production process and the way to reduce the energy consumption at different stages are presented below:

Production stage

- **Input of energy:** Energy requirements during production include fertilizers, agrochemicals, human and animal labour as well as fuels for mechanization, pumping and other activities.
- **How to reduce energy consumption on production stage:** Disease and pest management: Fungicide sprays for fresh produce can be accomplished using simple hand pumps, using perforated trays and drainage basins.

Harvesting stage

- **Input of energy:** Most horticultural commodities are harvested manually, including those grown in highly industrialized nations. Energy requirements during harvesting include mechanical energy for digging up root and tuber crops and to operate mobile field packing operations. Diesel and gasoline-powered equipment is also used for some harvesting activities. The challenge is to meet such growing energy demands with low-carbon energy systems and to use the energy efficiently throughout the production, transport, processing, storage and distribution of food (FAO, Sims, Flamini, Puri, Bracco, 2015). Harvesting activities require energy primarily for electric drives, electrochemical processes, lighting, refrigeration, heating, cooling and ventilation facilities
- **How to reduce energy consumption during harvesting:** Harvesting early in the morning when air temperatures are cooler helps reduce energy requirements and costs for cooling. Some Low-tech solutions for the curing, cleaning/washing, disease and pest management, sorting and grading, and packing of tuber crops can be introduced that lead to less energy intensive operations:

Curing of vegetable tubers and flower bulbs generally takes place directly following harvest to allow the external layers of skin and neck tissue to dry out prior to handling and storage. If local weather conditions permit, these crops can be undercut in the field, windrowed, and left to dry for five to ten days. The dried tops of the plants can be arranged to cover and shade the bulbs during the curing process, protecting the produce from excess heat and sun damage. The dried layers of "skin" then protect the produce from further water loss during storage.

Post-harvest stage

- **Input of energy:** Post-harvesting activities also require energy primarily for electric drives, electrochemical processes, lighting, refrigeration, heating, cooling and ventilation facilities. For example, cleaning/washing: If water is used, the energy cost for pumping and for cleaning the water will depend on how much produce moves through the facility, and how much water is needed to clean the produce. Cleaning root vegetables requires much more water than the amounts used to wash other types of crops.
- **How to reduce energy use at post-harvest stage:** Cleaning/washing: Spray washing, brushing, or wiping of produce in the packinghouse can be done by hand to reduce energy consumption. Sorting and grading: Sizing rings and colour charts can be used to visually sort and manually grade fresh produce. Simple tools such as rulers or calipers can be used to measure size or length. Packing: Hand packing in plastic crates, fibreboard cartons, or locally made containers lined with plastic bags can be done by count or by weight. Hand packing typically is used for all delicate produce, as well as for any place-packed or count-packed commodities. Natural air ventilation: Thermal chimneys can be added to existing structures or included in the design of new facilities to provide natural cooling of the packinghouse environment. As shown in Figure 5, air flow is greatly enhanced by the natural flow of air from cooler zones at the base of the structure and up through the warmed section and out. This type of ventilation is useful for cooling working spaces, but should not be used for storage rooms. Solar-powered fans can be used if passive ventilation is inadequate and other sources of electricity are not available. (USAid, 2009).

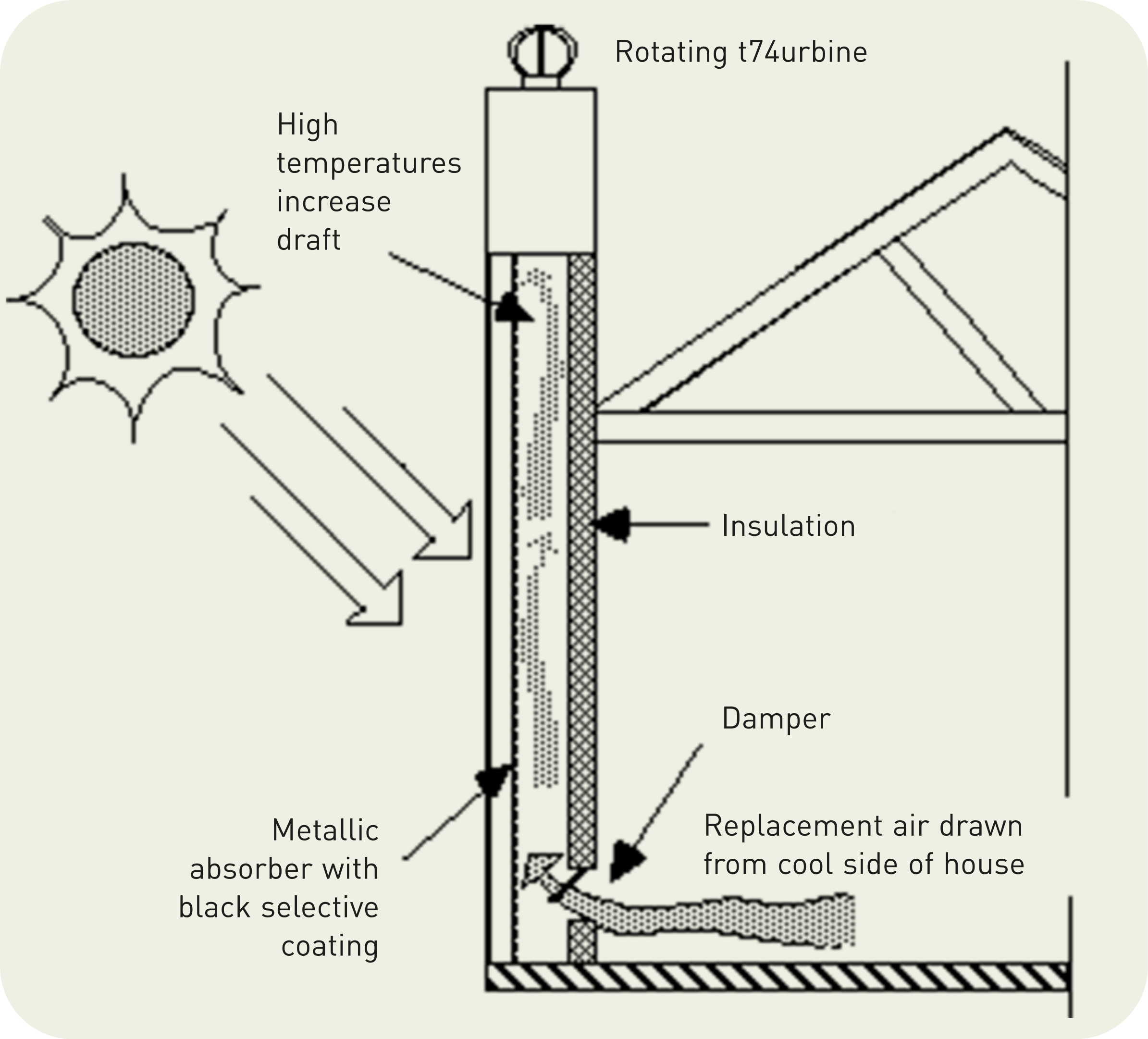


Figure 5 - Use of a thermal chimney for low-energy cooling
Source: Sustainable Building Sourcebook - Passive Solar guidelines-
http://infohouse.p2ric.org/ref/20/sourcebook/www.greenbuilder.com/sourcebook/PassSolGuide3.html

For post-harvest activities, energy efficiency is necessary to keep processing enterprises competitive, clean, and operating at peak productivity. As most processing activities rely on the use of heated water, this is an area where energy efficiency can be increased through improved innovation in energy systems. Table 1 below sets out conventional electricity and fuel requirements for water heating as calculated for both propane or natural gas heating.

Table 1: Electricity and fuel requirements for water heating

Ambient Water Temp (°C)	Target Water Temp (°C)	Water Flow (litres/hour)	Electricity use for Resistance Heating (kWh)	LPG Propane (litres)	Propane or Natural Gas (MJ)
20	40	400	9.2	1.5	38.0
20	52	400	14.7	2.5	63.3
25	40	400	6.9	1.2	30.4
25	52	400	12.4	2.1	53.1
30	40	400	4.6	0.8	20.2
30	52	400	10.1	1.7	43.0
20	40	1,000	23.0	3.8	96.1
20	52	1,000	36.7	6.1	154.3
25	40	1,000	17.3	2.9	73.4
25	52	1,000	30.9	5.1	129.0
30	40	1,000	11.5	1.9	48.1
30	52	1,000	25.2	4.2	106.3

(Source: Lenn Tech Energy and Cost Calculator for Water Heating, 2008 available at http://www.lenntech.com/calculators/energy-cost-water.htm and http://www.apricus.com/html/solar_energy_calculator.htm)

Temperature requirements depends on the commodity being treated, but normally ranges from 40 °C to 52 °C. It requires 9.2 to 14.7 kWh of energy to raise 400 L of water from ambient temperatures of 20 °C to 25 °C via resistance heating.

The figures in Table 1 assume that the heater efficiency for propane or natural gas heating is 85% and that the energy density of LPG/propane = 25.3 MJ/litre = 7 kWh/litre

By integrating simple RE technological solutions greater efficiency in energy use and a reduction in energy losses helps at any point along the agro-food chain that requires hot water. Solar water heating for example, can substantially reduce electricity or propane requirements and save up to approximately 80-90% of the fuel that would be otherwise required. Simple solar collectors can provide tangible increases in energy efficiency. A solar collector is the key component of an active solar-heating system. Solar collectors absorb energy and the resulting heat is transferred to water or air. Flat plate collectors are the most common type of solar collector for low-temperature water. Solar water heating can also substantially reduce electricity or propane requirements. Simple flat plate solar collectors with single glazing can be manufactured locally and are commercially available in most parts of the world, see Figure 6.

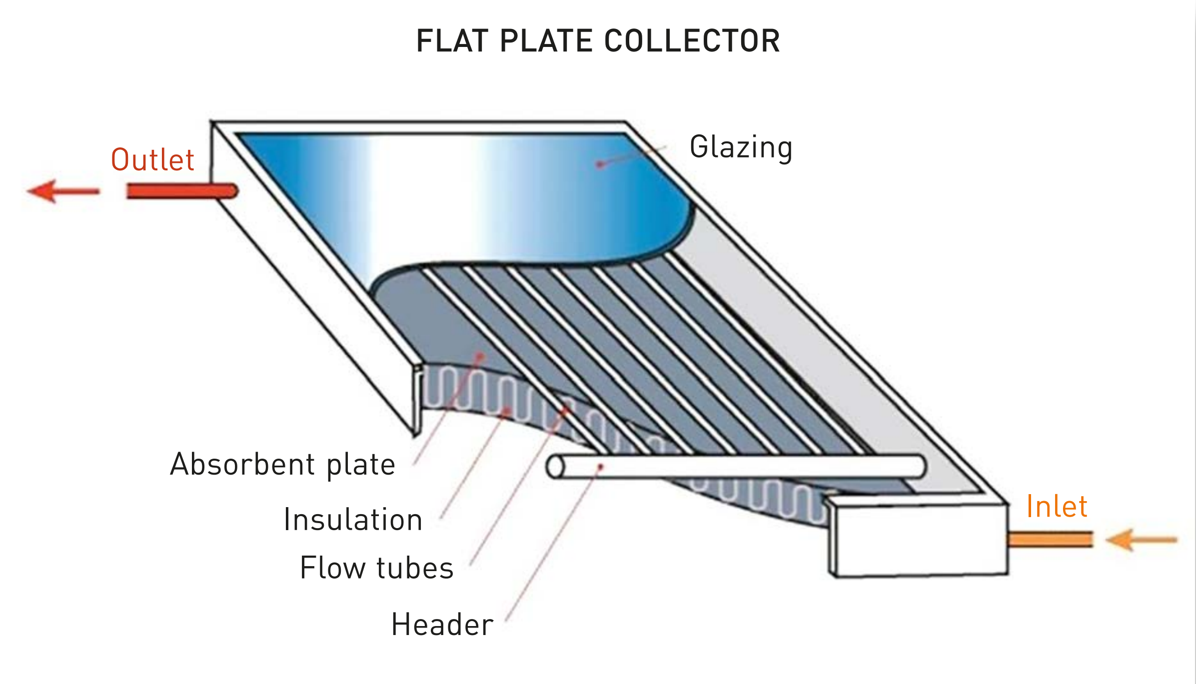


Figure 6 - Simple flat plate solar collectors with single glazing
Source: http://southface.org/solar/solar-roadmap/solar_how-to/solar-how_solar_works.htm

A typical flat-plate solar collector is made up of an insulated box (wood, metal, plastic, etc.) with a transparent glass or plastic cover and a black absorber plate. These collectors can produce water with temperatures around 80°C. The heated water is stored in a large outdoor black-painted tank and deliberately left exposed to the sun can increase the ambient water temperature to 30°C and reduce subsequent water heating by up to 30% or more.

Integral Collector Storage (ICS) for water heating also provides greater energy efficiency. In an ICS, the hot water tank is the solar absorber as detailed in Figure 7 below.

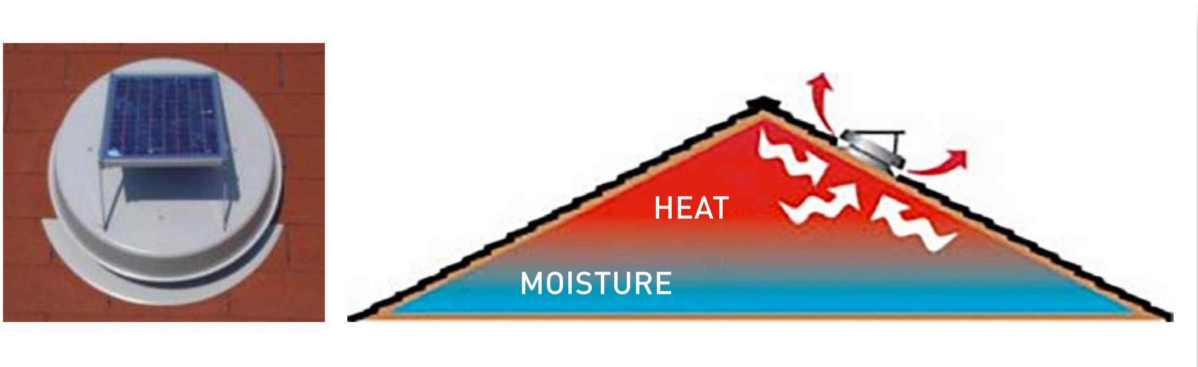


Figure 7 - Integral Collector Storage (ICS)
Source: Creative Energy Technologies Inc; http://www.cetsolar.com/12volt.htm

The tank(s) are mounted in an insulated box with glazing on one side and are painted black. The sun shines through the glazing and hits the black tank, warming the water inside the tank. Some models feature a single large tank (100 to 200L) while others feature a number of metal tubes plumbed in a series (100 to 200L) total capacity. The single tanks are typically made of steel, while the tubes are typically made of copper. These collectors weigh between 125kg to 200kg when full, so wherever they are mounted the structure has to be strong enough to hold this type of weight. Single glazed collectors similar to Table 6 have adequate efficiency for low temperature applications of less than around 50ºC. Higher temperatures require double glazing and higher levels of insulation around the collector (USAid, 2009).

Energy management programs that improve operational and technological efficiency are critical to the long-term success of the producing, processing, packaging, transporting and marketing that takes place along the agro-food chain. In order to execute these activities at some point **energy undergoes a conversion from one form to another.** This conversion process also has a role to play in **energy efficiency.** As previously discussed, decision makers really need to understand this process as it impacts on the selection and procurement process for energy intensive equipment, as well as for Energy Auditors when calculating or testing equipment.

2.2.2. Energy efficiency and conversion

As has been stated several times previously both in this and the previous Chapter, energy can be neither created nor destroyed but only converted from one form of energy to another. Also, the mathematical means with which to calculate energy efficiency when it is converted was discussed in Chapter 1. By way of more detail energy conversion is performed by equipment such as boilers, electric motors, pumps, blowers, lights and diesel generators. Table 2 lists some examples.

Table 2: Energy form conversions and equipment

Energy input	Equipment	Useful energy output
Chemically bound energy in coal	Steam boiler	Steam
Electricity	Electric motor	Mechanical shaft energy
Electricity	Incandescent light bulb	Visible light
Steam	Steam turbine	Mechanical shaft energy
Low voltage electricity	Step-up transformer	High voltage electricity
Mechanical shaft energy	Water pump	Flow work
Chemically bound energy in diesel fuel	Diesel generator set	electricity

Source - Energy Management Course Handbook 2017

Equipment responsible for the energy conversion process always produces some unused energy that is lost to the environment (but could be partially recovered) and discharged mostly in form of heat. Nevertheless, conversion happens when energy is generated i.e. a diesel engine generates energy, which means that the engine converts chemical energy of oil into mechanical energy. Also, a wind turbine generates energy, which means it converts kinetic energy from wind into mechanical energy. And a solar photovoltaic cell generates energy by converting radiation energy into electricity.

In summary, the generation of energy deals with a **source** of energy, whereas the utilisation of energy serves an end-use of energy. In between, the energy can flow through a number of conversion steps. The words "generation" and "utilisation" are a little confusing because, in fact, no energy can be created or destroyed. Energy is either transformed or converted into energy from one form into another. When energy is generated, it becomes available from a source, by converting it into another form. In utilising energy, it is also necessary to convert energy, often from some intermediate form into a useful form. In all conversions, part of the energy is lost. This does not mean that it is destroyed, but rather that it is lost for useful purposes, through dissipation in the form of heat or otherwise).

Table 3 below provides the detail of energy efficiency when one form of energy is converted to another.

Table 3: Examples of conversions and typical efficiencies when energy is converted

Converter	Form of input energy	Form of output energy	Efficiency %
Petrol engine	Chemical	Mechanical	20 - 25
Diesel engine	Chemical	Mechanical	30 - 45
Electric motor	Electrical	Mechanical	80 - 95
Boiler & turbine	Thermal	Mechanical	7 - 40
Hydraulic pump	Mechanical	Potential	40 - 80
Hydro turbine	Potential	Mechanical	70 - 99
Hydro turbine	Kinetic	Mechanical	30 - 70
Generator	Mechanical	Electrical	80 - 95
Battery	Chemical	Electrical	80 - 90
Solar cell	Radiation	Electrical	8 - 15
Solar collector	Radiation	Thermal	25 - 65
Electric lamp	Electrical	Light	ca. 5
Water pump	Mechanical	Potential	ca. 60
Water heater	Electrical	Thermal	90 - 92
Gas stove	Chemical	Thermal	24 - 30

(De plus amples informations sont disponibles à l'adresse : www.fao.org)

2.2.3. Minimisation and maximisation strategies

The most common example of calculating energy efficiency is a conventional power plant where heat is converted into electricity by using a turbine and a generator. In such thermal power plants, energy input would refer to the heat fed into the process and electricity obtained as a useful output. Both elements are energy flows and can be quantified by using thermodynamic calculations which result in an absolute value for efficiency. Unfortunately, such a straight forward procedure is not always applicable. Therefore, after the results and recommendations of an Energy Audit become available farmers or enterprises might chose to adopt what are commonly known as **maximisation** or **minimisation** strategies to improve overall energy efficiency.

2.2.3.1. General principle

Efficiency always involves both used resource and provided services. Therefore, efficiency can be improved if the same service is provided using fewer resources- **minimization strategy**, or if a better service is achieved with the same resource consumption as before- **maximization strategy**. These two scenarios are often referred to as minimization and maximization strategy, respectively.

Let us look at a simple example: One person pushes a wheelbarrow with oranges on a flat surface over a distance of ten metres. Here the used resource is the energy of the person while the service or output is pushing the wheelbarrow with oranges ten meters. Now let's add that the person uses something to reduce friction between the surface and the wheelbarrow. The person can either go with the **maximization strategy** and push the wheelbarrow with oranges further with the same energy used as before or the person can push the wheelbarrow over the same distance (ten meters) and use less energy – this would then be called a **minimization strategy**. Mathematically, both ways have the same efficiency improvement. However, one way aims to reduce the input resource while the other way wants to extract as much as possible out of the resource. It can be concluded that, increasing efficiency does not necessarily mean to save resources. In this small example the resource described is the muscle energy of a person. In other systems, the used resource can be natural resources, money, labour, material or even time. As in many cases the goal is to make processes better, we strive to increase efficiency.

2.2.3.2. Maximisation strategy

Changing a system in which power and heat are conventionally generated in separate generation cycles while waste heat remains unused to a) a more efficient system with heat reuse and heat recovery or b) even to a combined heat & power supply (co-generation facilities) system.

- **Example A. System of heat reuse and heat recovery**

This could e.g. mean waste heat from power generation process in power plants or from industrial production processes or others is used for other nearby cooling/ heating demands such as dairy production, greenhouses or other agro food related facilities.

- **Example B. Combined heat and power supply/co-generation facilities**

Briefly, co-generation systems are increasing in popularity and in fact will become one of the core energy technologies for the profitable production of both heat and electricity for localised electricity and heat distribution networks. A cogeneration unit generates electricity and heat in just one device. Production takes place simultaneously in Combined Heat and Power (CHP) modules. The main element of a CHP module is the high-efficiency gas engine in which, as a result of the combustion process, converts energy contained in the fuel into thermal and mechanical energy. Mechanical energy can be converted into electricity, because of the synchronous generator coupled with the engine. The energy in the exhaust gas and the heat loss from the engine is recovered through heat exchanges and then made available as thermal energy. The thermal energy made available can be distributed to various customers via a distribution network (further more detailed information is available at http://aceee.org/topics/combined-heat-and-power-chp).

Due to the simultaneous generation of heat & power on-site and in a decentralized way, co-generation plants reach aggregate efficiencies up to 80-95% compared to efficiencies of separate generation processes of around 50%. To cover heat, power and even cooling demands in one combined and efficient generation, also a 'tri-generation' system can be applied in agro-food production processes.

2.2.3.3. Minimisation strategy: replace incandescent light bulb with a LED light bulb

Modern light bulbs with LED technology are able to provide a light with brightness or more accurately, with visible light of 1000 lumen with electricity input of 20 Watt. On the other hand, the old incandescent light bulb technology needs five times more electricity input to provide the same brightness of visible light. Using Equation 1, we can actually see the difference in numbers:

$$\frac{\text{LED bulb} = \text{Output} = \text{Brightness} = 1000 \text{ lumen} = 50 \text{ lm}}{\text{Input Power } 20 \text{ watt W}}$$

$$\frac{\text{Incandescent light bult} = \text{Output} = \text{Brightness} = 1000 \text{ lumen} = 10 \text{ lm}}{\text{Input Power } 100 \text{ watt W}}$$

The LED uses the input resource in a more efficient way. However, this comparison is only acceptable when the output or service is really the same in both technologies. In the case of a light bulb, for some people brightness is the only important factor. Others might argue the LED provides a different light colour and therefore a different or less valuable service than the incandescent bulb.

"Therefore, it is worth distinguishing between quality and quantity of output service. Evaluating the quality of services is generally difficult, especially when multiple services are provided by the system subject to analysis (Pérez- Lombard, *et al.*, 2012)".

As a result, the focus is on evaluating the quantity of output service, which can be measured more easily.

Good and relevant examples of how small to medium enterprises, in this case flower farms in Kenya, were able to implement minimisation strategies in order to increase energy efficiency. It took the following forms:

- Standard electric motors were replaced with energy efficient motors.
- Variable speed drives were used in fertigation and irrigation pumps wherever variable amounts of water are required.
- Use of high efficiency lighting to replace fluorescent lights with magnetic ballasts.[4] In the case of flower farms LED lights, T5 fluorescent fittings[5] and replacement of existing electro-magnetic ballasts with electric ones.
- The rationalisation of irrigation pumping which although is not technically a minimisation strategy works to conserve energy consumption. In this case, 'pumping' was revised to deliver the same quantity of water that is required on a daily basis with appropriate pressure head at the furthest points and avoiding the throttling pumps increased pumping efficiency to 65%. These measures resulted in significant energy savings and the payback period was one month.
- Installation of heat recovery systems to recover heat from cold room refrigeration systems. The recovered heat is used to preheat water for flower propagation nurseries.

While these minimisation strategies involve minimal investment on the part of the flower farms they have only proven to be really effective when combined with other measures such as grid connection, pilot bio-gas plants, etc.

More detailed information can be found in Kenyan Flower Industry – Potential for Renewable Energy Use, Federal Ministry of Economic Affairs and Energy, Berlin available at https://www.german-energy-solutions.de/GES/Redaktion/DE/Publikationen/Marktanalysen/2015/studie_2015_subsector-flower-industry-kenya.pdf

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[4] A magnetic ballast is a type of electrical power regulator used in fluorescent light systems. The ballast's output should precisely match the electrical requirements of the light it regulates. Source: https://www.maximumyield.com/definition/3116/magnetic-ballast.

[5] T5 LED tubes are currently offered as a plug-and-play version. As long as the LED tube is compatible with the fluorescent ballast, a plug-and-play is as simple as plugging in the tube light. Most LED tubes are compatible with electronic, programmed start, or instant start ballasts, but this is not always the case. Source: https://www.1000bulbs.com/category/t5-led-tube-lights/ https://www.1000bulbs.com/category/t5-led-tube-lights.

It is important to look closely at the denominator of the efficiency equation (the energy input). When comparing different technologies with another not only the end use appliances (like a light bulb) might be changed but also the form of energy input. For example, changing a system in which power and heat are conventionally generated in separate generation cycles while waste heat remains unused to a a) more efficient system with heat reuse and heat recovery or b) even to a combined heat & power supply (co-generation facilities) system.

2.2.4. Use of an energy calculator

In a home or business, energy efficiency efforts often begin with a site visit by an energy

professional who conducts an *energy audit*. The auditor inspects energy-consuming processes and equipment, and prepares a report describing possible changes that could reduce energy consumption or cost. This approach is not always available to small landholders or enterprises from the ACP countries because of the logistics and costs involved.

Small farms use modest amounts of energy, and cannot justify the expense of a professional energy audit, Farms are complicated 'holistic' operations. Changes in one process may require re-thinking or adjusting several others. The engineering professionals who have the technical skills to do energy audits very often have little or no experience with farms.

As an alternative to a site visit by an energy professional, do-it-yourself energy assessment tools have an obvious appeal. Agricultural producers or processors tend to be resourceful, handy, and knowledgeable about their own equipment and generally capable of making their own energy-saving improvements. An important question, therefore is: to what extent can self-help tools substitute for an on-site visit and audit by an energy professional?

The answer for small landholders or small enterprises is that, if the technology is available, then it is far more practical and cost-effective to use a simple energy calculator yourself.

Calculate usage

Be better informed

Save money = help the planet

For larger agro-food enterprises an online **energy calculator** is a tool that enables the user to estimate energy consumption and cost and identify energy-saving opportunities. Most energy calculators today are computer-based, and dozens of these tools have recently appeared on the Internet. Thus far not very much has been known about the usefulness of these tools for agricultural producers and/or processors.

The term 'calculator' is used broadly here, to include a wide variety of energy awareness and decision-making tools. Most of these tools do far more than just mathematical calculations. Most focus on energy efficiency and conservation, although a few renewable energy tools and greenhouse gas calculators are also available.

The focus of a farm energy calculator can be as narrow as an individual piece of equipment such as a tractor block heater or electric irrigation pump or as broad as a whole farm. Among the broader tools, some include energy within a larger context. The simplest online calculators have a checklist or multiple-choice format. The user chooses from options on the screen, often with knowledge off the top of the head regarding fuel costs, equipment types, acreage, or location. Some calculators offer default values, while giving the user the option of typing in a more accurate value if one is known.

A slightly more interactive approach combines checkboxes with numeric entries. These numbers may be readily-known, like postal codes or current fuel prices, or they may require basic research on the part of the user, such as monthly electric bill rates, or equipment horsepower. More in-depth calculators require more research and record-keeping, asking, for example, about lighting wattages or the number of hours that a piece of equipment runs each day.

A next step in complexity is the online spreadsheet, where the user locates the correct cells for inputs and types in numeric values. Some spreadsheet-style calculators allow the user to create an account and store values. This makes it possible for the user to run multiple scenarios with alternative inputs or return to the calculations at a later time.

At the far end of the complexity spectrum are software programs, made available for downloading from the Internet. These tools are installed on the user's own computer, alleviating privacy concerns. However, these programs require a commitment of time, computer skills, and computer memory that may discourage the casual user. (More detailed information can be obtained from Farm Energy Calculators, NCAT June 2009, available at https://www.ncat.org/downloads/FE_Calculator_Report_Final.pdf)

Below is a sample of the various types of energy calculators available online that are provided by a spectrum of organisations or companies that have an interest in supporting on-farm and off-farm energy efficiency.

Caterpillar Energy Solutions GmbH – http//chtp-calculator.mem.net/

Description:

Online combined heat and power (CHP) calculator of reputable CHP manufacturer:

https://www.epa.gov/chp/chp-energy-and-emissions-savings-calculator

https://solarturbines.secure.force.com/cogeneration; http://chp-calculator.mwm.net/

Applies to industrial and commercial applications 400-4500kW. The tool includes financial analysis based on the return on investment. Focus is on gas-engines including biogas and sewage gases. Allows user input for installation country and fuel types.

Accessibility: Online – No registration required – Free of charge

Additional downloads:

- **EU Directive for CHP with interesting equation to calculate primary energy savings of a CHP**
  http//:eur-lex.europa.eu/legal-content/EN/TXT/PDF/?url=CELEX:32004L0008&from=EN
- CHP efficiency metric of the EPA (USA) with definitions:
  https://www.arb.ca.gov/cc/ccei/presentations/chpefficiencymetrics_epa.pdf
- EPA manual and equations to calculate the energy and environment performance of a CHP facility as compared to the separate generation of heat and power. Based on American units.
  www.strath.ac.uk/research/energysystemsresearchunit/
- EPA calculator as Excel spreadsheet download for CHP:
  https://www.epa.gov/chp/chp-energy-and-emissions-savings-calculator
- CHP good practice design for buildings and commercial operations such as hotels and hospitals and any other business requiring process heat and power:
  www.cwp-ltd.com/
  www.wbdg.org/resources/combined-heat-and-power-chp

Additional Web pages:

- Comprehensive EPA site exclusive for CHP
  www.epa.gov/chp
- CHP summary of EPA
  www.epa.gov/chp/methods-calculating-efficiency

eQuest – www.doe2.com/

Description: Complete building design and energy efficiency peformance tool for all climate conditions. The eQuest desktop software (100mb download) is based on the standard DOE-2 building energy simulation program that has been perfected over the last twenty years. Contains only USA related data therefore a user must provide its own data or select a similar USA climate region. The software is most useful for EA that provide regular services for all kinds of industrial, residential and commercial buildings.

Accessibility: Online Download Free of charge

Additional downloads:

- Overview of the software and its capabilities:
  www.doe2.com/download/equest/eQUESTv3-Overview.pdf
- Introductory tutorial to obtain a first idea of what is important
  http//:doe2.com/download/equest/eQ-v3-64_Introductory-Tutorial.pdf

Additional Web pages: None

Air Technologies Energy Calculator: www.aircompressors.com/resources/energy-calculators/

Description: Very practical Excel spreadsheet calculators in American and Si units for compressor energy, filter pressure drops and oil carryover, installation pipe work, load duty cycles, pressure/volume, and pressure drop cost. Formulas are not provided.

Accessibility: Online Download Free of charge

Additional downloads:

- Excellent compressed air manual for training and classroom teaching
  www.atlascopco.com/images/Compressed_air_Manual_tcm30-1249312.pdf
- **A complete example of a real compressed air energy efficiency audit**
  wwww.plantservice.com/
  https://www.airbestpractices.com/system-assessments/compressor-controls/compressed-air-auditing-101

Additional Web pages:

- **ISO standards on compressed air energy efficiency assessment**
- 'Use your energy twice' air compressor heat recovery
  https://www.carbontrust.com/media/147009/j7967_ctl166_how_to_recover_heat_from_a_compressed_air_system_aw.pdf
  https://www.compair.com/pdfs/brochures/en/Heat_Recovery_Brochure.pdf
  https://www.airbestpractices.com/technology/air-compressors/air-compressor-heat-recovery
  https://www.pneumatictips.com/can-air-compressor-heat-recovered/
- Air compressor cost effective waste heat recovery calculator
  http://www.kaeser.com/int-en/services/know-how/calculator/heat-recovery/
  https://www.engineeringtoolbox.com/ventilation-heat-recovery-d_244.html
- Sustainable energy authority of Ireland compressed air calculators.
  This site www.seai.ie also provides more online calculators and a most useful emission mitigation calculator. Search the site for 'calculators'
  www.seai.ie/Your_Business/Technology/Industry/Compressed_Air_Option_Calculator.xls

Source – Energy Audit Course Handbook for a 200-hours training course for engineers 2nd Edition, May 2017

- Simple calculator with tutorial with which to estimate efficiency not based on any standard https://www.tlv.com/global/TI/calculator/boiler-efficiency.html
- Simple however more sophisticated calculators to estimate boiler efficiency not based on a standard https://www5.eere.energy.gov/manufacturing/tech_deployment/amo_steam_tool/equipBoiler

Some other less technology intensive energy saving practices that can be implemented along the various behind and beyond the farm gate points along agro-food chains can be implemented to increase energy efficiency and are detailed in Table 4 below:

Table 4: Energy Saving practices that can be implemented along agro-food chains

WHICH ENERGY (SERVICE) DEMAND?	WHICH AGRO-FOOD PROCESSES/VALUE CHAINS?	WHICH COMMON ENERGY EFFICIENCY TECHNOLOGIES/ MEASURES?
Heat supply	• Greenhouse farming • Food processing (dairy production, drying fruits & vegetables, canned food etc.)	• CHP (combined heat and power)/ co-generation • Waste heat recovery (e.g. by heat exchangers that use 'waste' heat for pre-heating other processes) • waste heat from (nearby) power plants • Insulation of networks/ pipeline, building facilities • Where possible/ feasible using renewable sources for heating demands (e.g. solar thermal, geothermal, also by heat pumps, bioenergy heat plants etc.)
Cooling & air conditioning / cold storage / cooling chains	• In all agro-food sectors where food quality needs to be maintained after harvesting, while processing and for transporting agro-food products => dairy/ milk production, rice production, vegetable production, beverage industry, drinking water treatment and processing etc.	• CHP/ tri-generation • Insulation of networks/ pipeline, building facilities • Minimizing heat load at the end of the processing phase of the cold chain • Efficient and 'climate friendly' refrigeration systems (also with new/ renewable technologies are available, such as solar absorption chillers) • Efficient greenhouse ventilation systems
Fertilizer	• In many agro-food sectors/ processes	• Reducing heavy energy inputs in fertilizer and pesticide manufacturing • Improving accuracy and timing of applications, with biosensors for soil fertility monitoring and trace gas detection. This can significantly reduce fertilizer usage and thus decrease energy inputs. • Improving accuracy and timing of pesticide application by taking measuring such as timely calibration of the knapsack sprayer but also by applying IPM.

WHICH ENERGY (SERVICE) DEMAND?	WHICH AGRO-FOOD PROCESSES/VALUE CHAINS?	WHICH COMMON ENERGY EFFICIENCY TECHNOLOGIES/ MEASURES?
Water supply/ pumping	• Many agro-food processes (growing, harvesting, processing)	• Correct gear and throttle selection • Efficient automation (efficient electric drives & motors, as well as automate monitoring & control systems) for production and processing
Transport and distribution of food	• Transport of food commodities (such as milk powder, rice in bulk, fruits and vegetables etc.), partly under controlled atmosphere or refrigeration	• Efficient and 'climate friendly' refrigeration systems (also with new/ renewable technologies are available, such as solar absorption chillers)
Processing & packaging of food	• Many agro-food chains and their sites for processing agro-food products or food/ beverages	• Efficient automation (efficient electric drives & motors, as well as automate monitoring & control systems) for production and processing
Renewable energy and stable energy supply	• All along the value chain in many agro-food sectors • Where good local energy resources exist • Where stable power/ energy supply is need (e.g. for continuous cooling demands; heating on high temperatures etc.)	• Using grid electricity with a growing share of renewables (solar, bioenergy, geothermal etc.) • Improving & modernization of power grid (centralized and decentralized networks)
(Lighting)	• Greenhouses • Production, processing and storage site	• Energy saving lighting technologies (e.g. LED) • Efficient automatization of lighting (matching real demands)

Adapted from Powering Agriculture: An Energy Grand Challenge for Development available at https://poweringag.org/mooc

To improve energy efficiency it is important to identify areas where energy consumption can be reduced. Some steps that can be taken to arrive at energy efficiency are:

- Regular reviews of energy use by paying attention to energy bills or past fuel consumption patterns.
- Undertake site assessments to record equipment being used and performance data.
- Perform a technical and cost analysis. For the technical analysis a simple energy balance can be undertaken.
- Draft action plans to identify what energy efficiency measures can be taken to improve cost and energy savings.

2.2.5. Steps to rationalise inputs and costs

As already stated energy efficiency is a continuous cycle as detailed in Figure 8 below. Therefore, it is very important to monitor and to identify ways to save more energy using the tools and methodologies provided in this section. Also, by developing a relevant and comprehensive energy management system for each sized enterprise. By learning how and when energy is consumed on the farm and beyond the farm, new ways can be found to adjust agro-food chain practices to save more. This provides input for the next round of efficiency improvements.

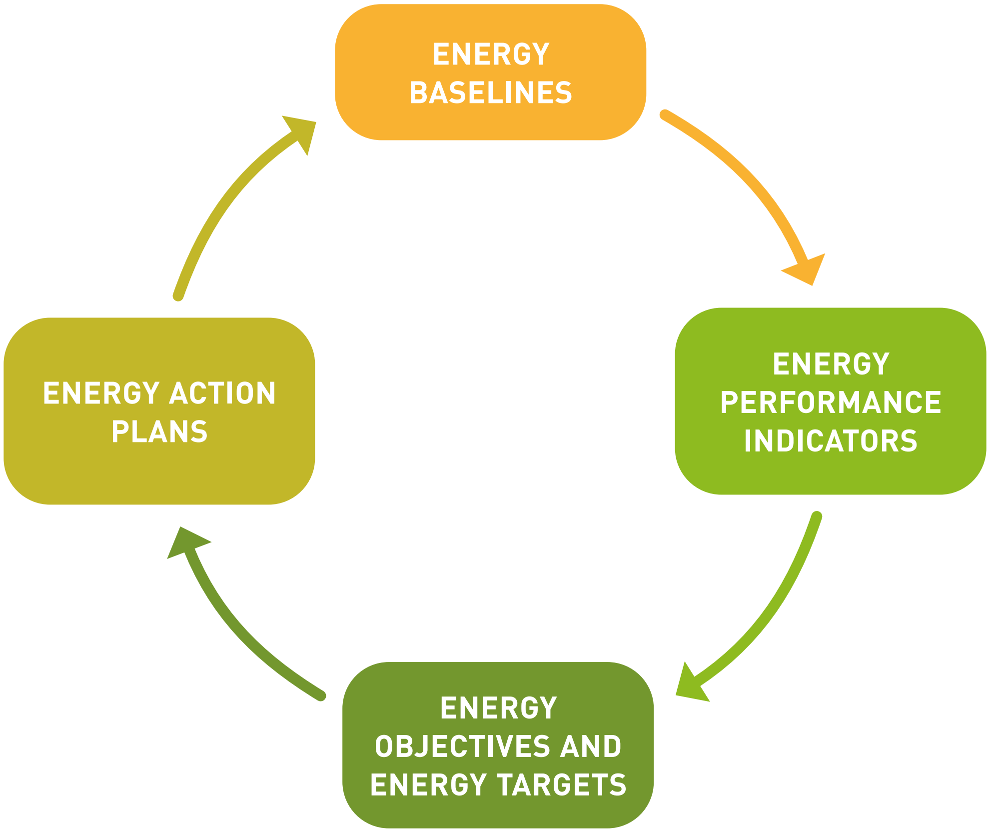


Figure 8 - Energy efficiency cycle

For small to medium enterprises, or those enterprises that are involved in complex processing, packaging, transportation or marketing it may help to train a staff member(s) that is (are) involved in Energy Management (refer to Chapter 1 for more detail on this topic) to develop an **energy baseline** based on **energy performance indicators** to be incorporated into energy management systems or to assist with energy audits.

2.2.5.1. Energy baseline

The Energy baseline is summary of the total energy use defined for reference period and reference parameters of production.

The idea is to take the information from the initial energy review while considering a data period suitable to the enterprise's energy use and consumption. Changes in energy performance are measured against the original energy baseline(s). Baselines need to be adjusted in the case of one or more of the followings:

- **Energy performance indicators** no longer reflect organisational energy use and consumption,
- There have been major changes to **the process, operational patterns, or energy systems**,
- According to a **predetermined method** as defined in the procedure.

2.2.5.2. Energy performance indicator

As you can't manage what you don't measure! Measurement data can be obtained from an energy audit (Chapter 1 provides a detailed discussion of the Energy Audit process). Before measurements can be made, it is necessary to define certain elements known as **indicators**.

The enterprise should identify energy performance indicators (EnPI) appropriate for monitoring and measuring the system's energy performance. The methodology for determining and updating the EnPIs is established in the energy management system procedures and records are maintained. The EnPIs are regularly reviewed and compared to the energy baseline as appropriate.

Highly industrialised operations are generally complex, involving many sub-activities with a high level of variability. Consequently, indicators should be defined as precisely and accurately as possible, outlining both the scope and boundaries and identifying the applied metric. Indicators should preferably be in line with the requirements of ISO 50001 to allow for comparison and internal and external benchmarking. When evaluating energy efficiency based on indicators, care must be exercised to compare like categories. Indicator values will reflect energy efficiency achieved through system enhancements and specific improvement projects, but the overall values will vary greatly depending on many factors. The various types of indicators used are as follows:

- **Indicators based on operational data (Leading and Lagging):** Energy performance is commonly assessed with 'lagging indicators' which are retrospective metrics based on actual operational data, reflecting the 'was-is' situation of energy performance. Leading indicators lead performance, and

Lagging indicators lag performance. In other words, the former type of indicator identifies where the performance of assets, teams or resources are going to, and allows for proactive management. Whilst the other type of indicator identifies where it has been and allows for reactive action.

- **Operational level indicators:** These indicators are typically relatively simple process functions calculated on a semi- or fully- continuous basis in order to *measure and monitor energy usage over the short term*, down to a single unit or facility. For instance, in the case of a brush cutter, an indicator can be the heating fuel consumption per square meter of weeds mowed in one week. Operational level indicators are commonly developed for each site and each processing entity according to the specific local situation.
- **Site level indicators:** These indicators are based on *aggregated data* from the site and are commonly calculated on a *quarterly or yearly basis*. They serve to measure and monitor the energy efficiency of the site over time and/or against peers. ***Absolute energy consumption*** (in units of energy per year) may be used for management and/or financial reporting purposes but is of little interest as an energy performance indicator because it does not refer to the corresponding level of activity. ***Specific energy consumption***: (Expressed in units of energy per processed production unit) is a commonly used indicator. It is often referred to as energy intensity. This is of limited use for the comparison or benchmarking of facilities of different complexity or varying asset types (production and processing areas, buildings, storage, etc.). As a result, each operating area has its own structural energy consumption that reflects the specific tasks that it carries out.

A systematic review and analysis of energy consumption forms the basis for enhanced energy efficiency. The higher the consumption the more detailed the measurement should be and, consequently, the easier it is to ascertain the savings potential. These measurements are restricted by measurement costs, which should naturally not exceed the benefits In addition to consumption data, there are other relevant factors which should be included to enable a comprehensive assessment of data. In order to maintain clarity, it makes sense to take into account the entirety of an operation, as well as individual areas (e.g. equipment, sites, and facilities), systems and processes. However, system boundaries and operational conditions should always be determined. These can be, for example:

- Measurement interval (time, duration) and measurement accuracy
- Production stages, type of product, locations or even areas of building equipment and appliances (lighting, ventilation, etc.)

It should always be possible to explain irregularities. Therefore, alongside data for energy consumption and use, it is useful to record production figures, turnover and breakdowns.

During the energy review, identify the age of your equipment and resources, as well as any visible defects. In order to determine the savings potential and to identify changes, the complete energy flow of the enterprise should be recorded and documented.

2.2.5.3. Energy objectives and energy targets

Energy objectives and targets for relevant functions, processes, facilities, and levels within an enterprise are prepared, documented, and implemented as performance indicators based on the energy policy. Targets should be based on all parameters that decisively impact energy consumption. All objectives and targets must be made measurable and consistent with the energy policy of the enterprise, including commitments to comply with the applicable legal framework and other requirements which form the basis for continual improvement. A realistic time frame for the achievement of the objectives and targets should also be defined.

2.2.5.4. Energy action plans

Preparing, implementing and maintaining an energy action plan will ensure the achievement of all defined objectives and targets. The energy action plan shall include:

- The items that requires action including the action that needs to be taken.
- (Financial) means and time frame for achieving objectives and targets.
- The function (person) within the organisation responsible for achieving the objectives.

Energy efficiency is a continuous cycle. It is in the best interests of any sized enterprise along the agro-food chain to invest time, energy and money to continuously improve the efficient use of energy by paying attention to the following:

- Energy baselines
- Energy performance indicators
- Energy objectives and energy targets
- Energy management action plans

2.3. UNDERSTAND HOW TO LIMIT ENERGY CONSUMPTION IN A FARM/COMPANY

The magic formula with which to determine if a switch from fossil fuel energy to RE technologies, or a mix of both is required to improve energy efficiency depends on the '**energy balance**' of an enterprise.

An **energy balance** is a consideration of the **energy** input, output, and consumption or generation in a process or stage. In establishing an **energy balance**, all sources of thermal **energy** are put on the input side, and all items of heat utilization on the output side

The golden rule to apply in such scenarios is that '**you can't manage what you don't measure.** The question to be asked is: **If you don't know where you spend how much on which energy, how can you identify savings?** In other words if you do not know how much energy is lost from the system how can you determine how to best invest or manage an energy system?

To better understand the necessity to undertake an energy balance it is practical to draw from the first law of Thermodynamics which states:

"Energy can neither be created nor destroyed"

As previously discussed in this Chapter, whatever humans or their machines do involve the conversion of one form of energy input into at least two other forms of energy output. One form is the output of useful energy. The balance is energy loss (as has been demonstrated many times in the previous sections that relate to energy inputs and losses from agro-food chains). The sole objective in this context is to change the system in such a way that the technical losses are reduced in a cost-effective way. The management of energy systems therefore has to overcome three basic challenges:

- How to specifically define the system being considered? and,
- How to quantify energy flows into and out of that system?

2.3.1. Define system boundaries

The first of these challenges involves defining a **system boundary**. As noted above, the definition applied to "system", is any energy-consuming building, area within a building, operating system, collection of equipment, or individual piece of equipment around which a boundary can be figuratively placed. What happens *within* the system boundary is of little concern from an energy accounting standpoint. The energy streams that *cross the boundary* must be accounted for. **It is therefore essential that the system boundary be defined in very specific terms.**

2.3.2. Collect data

The second of these challenges is the more difficult in technical terms, as it involves the collection of energy flow data from various sources, including direct measurements. The estimation of energy flows that cannot be directly measured, such as heat loss through a building wall, or in vented air, is likely also to be involved. The concern is with the energy flows that cross the system boundary as it has been defined. The following points must be considered when quantifying energy flows:

- Select convenient units of measure, and be able to convert the various units to one selected unit for the consolidation of data (e.g. express everything in equivalent kWh or MJ of energy);
- Know how to calculate the energy contained in material volume and mass flows – as in hot water to drain, cooled air to vent, intrinsic energy in processed materials, etc.;
- Know how to calculate heat from the various precursor energy forms, as in electricity converted to heat through the operation of an electric motor (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2017).

2.3.3. Awareness of employees

The third of these challenges relates to the awareness of employees regarding the purpose of energy management. Therefore, if energy management is to be both successful and accurate employees need to be aware of the following:

- Energy policy, objectives and targets
- How individuals can contribute to energy management
- Information on energy consumption and trends within the company
- Compliance with legal and other requirements
- Room for improvement
- Financial and environmental advantages of energy management
- Contact person(s) for further details

Far more detailed information can be obtained by consulting ISO 50001 as it relates to internal communication requirements for agro-food chain enterprises and the successful management of energy. In addition, the value of training programs should not be underestimated. Well-designed training programs help to encourage the relevant and necessary employee competencies in the enterprise, as well as raise awareness of the importance of energy management amongst employees.

2.3.4. Establishing an energy balance: a practical example

In terms of practice and application, the steps that needs to be taken towards establishing an energy balance:

1. Make a list of all energy inputs
2. Identify where significant amounts of energy are used
3. Identify the specific Energy Performance Indicators
4. Develop an Energy Action Plan
5. Identify the specific Energy Objectives and determine how to monitor them.

To better understand the importance of an energy balance in determining '*you have to know what you have before you can manage it*', follow the practical example that follows.

2.3.4.1. Introduction

Dushi is a family company that has been cultivating Yard long beans for more than three generations. Jack and his wife Jill – together with three full-time and two half-time employees - cultivate yard long beans on 5 hectares of land. They produce 35 tons per year and provide only the local market with their nutritious and tasteful yard long beans but dream of exporting them to Germany.

For their daily operations they make use of:

- 1 tractor for amongst others ploughing the land and transporting the Yard long beans from the fields to the packing house;
- 2 brush cutters for mowing weeds and grass;
- 2 pumps for irrigation of the fields in dry seasons;
- Lightning on the farm for amongst other the packing house storage area pesticides, fertilizers, equipment etc;
- Small equipment for sorting, grading and packing;
- 1 cold storage room for the storage of packed Yard long beans;
- IT and other (electronic) office supplies;
- 1 small reefer truck for the distribution of Yard long beans under controlled temperatures from the storage room to the customer.

Jack and Jill have heard that there are ways to reduce energy costs for small farms. They take part with other farmers in their region in a project to help them introduce basic energy management techniques.

The steps to implement these techniques according to the manual are:

1. List of energy inputs: how much do we actually pay for energy?
2. Significant energy uses: where is the energy being used?
3. Energy performance indicators: how can we track our energy consumption in the future?
4. Energy action plan: how can we reduce our energy costs?
5. Energy objectives & monitoring: where do we want to go- and are we on track?

2.3.4.2. Make a list of all energy input

How much do we actually pay for energy?

Before you start collecting and analysing data, check if the following documentation is available in the company:

- Records on energy consumption and consumer structure (e.g. machinery lists);
- Plans, programmes, audit reports, measurements, etc.
- Meter readings from utility company etc.
- Bills, invoices from utility companies, fuel suppliers etc.

Data on the annual consumption as well as costs have to be collected separately for each type of energy. These data are available in the invoices of the energy suppliers (electricity, district heating, gas) or suppliers of heating oil or diesel as well as in records of the in-company petrol station or electricity plant, etc.

Data should be collected separately for the following types of energy: electricity (energy supplier), in-plant electricity generation (hydropower, photovoltaics); natural gas, heating oil (heavy, light, extra light), fuels (diesel, petrol), biomass, solar power and district heating.

Jill collects all the fuel and electricity data from utility bills and supplier invoices from the last years. She uses a simple Excel-table to list them:

Table 5: Energy inputs

Energy-Input		Consumption				Costs [US$]			
Unit	2014	2015	2016	2017	2014	2015	2016	2017	2017
kWh	170,876	199,556	201,877	214,512	5,126	6,386	7,066	8,580	8,580
Litre	1,420	1,400	1,450	1,500	994	1,008	1,088	1,185	1,185
Litre	61	59	68	65	48	47	56	55	55
Total Costs						6,168	7,441	8,209	9,820

It can be seen that in 2017 the average retail electricity price stands at $0.04/kWh, the average diesel price at $0.79/litre and the average petrol price at $0.84/litre.

Energy consumption is measured in joules (J, kJ, MJ, GJ). A further common unit is kWh: 1 kWh equals 3600 kJ. Energy sources, such as fuels, are also stated in kilograms (kg), standard cubic metres (scm) or litres (l). Conversion factors can be found in the Excel-table A3-1.

Besides the energy consumption, power is also an important factor. It indicates how much work is performed within a specific time and is usually measured in watts (W, kW, MW, GW). For example, electricity is usually billed on the basis of two distinct quantities:

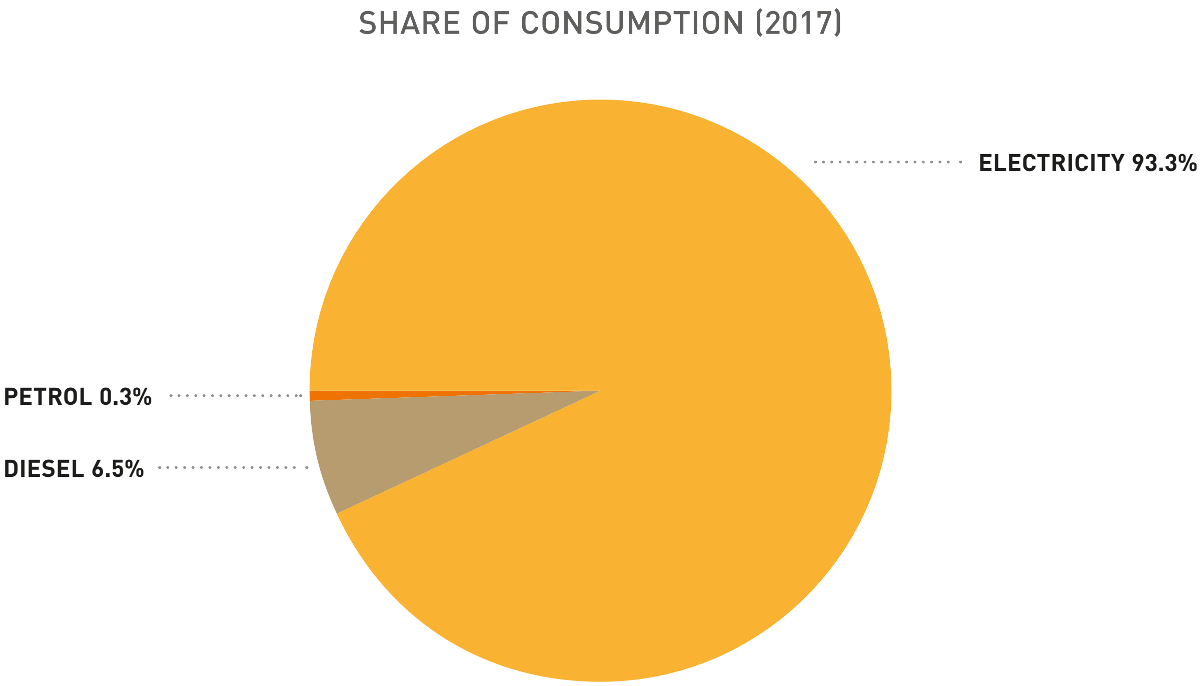
- Power (kW) and
- Consumption = work (kWh)

In order to compare the different units of energy better, they can be converted into kWh using common conversion factors:

Table 6: Energy input in kWh

			Consumption [kWh]			
Energy Source	Unit	Conversion factor in KWh	2014	2015	2016	2017
Electricity	kWh1	1	170,876	199,556	201,877	214,512
Diesel	Litre	9.9	14,058	13,860	14,355	14,850
Petrol	Litre	8.85	540	522	602	575
Total			**185,474**	**213,938**	**216,834**	**229,937**

Using the Excel-table from the manual, Jill can produce some diagrams to better understand their energy consumption:



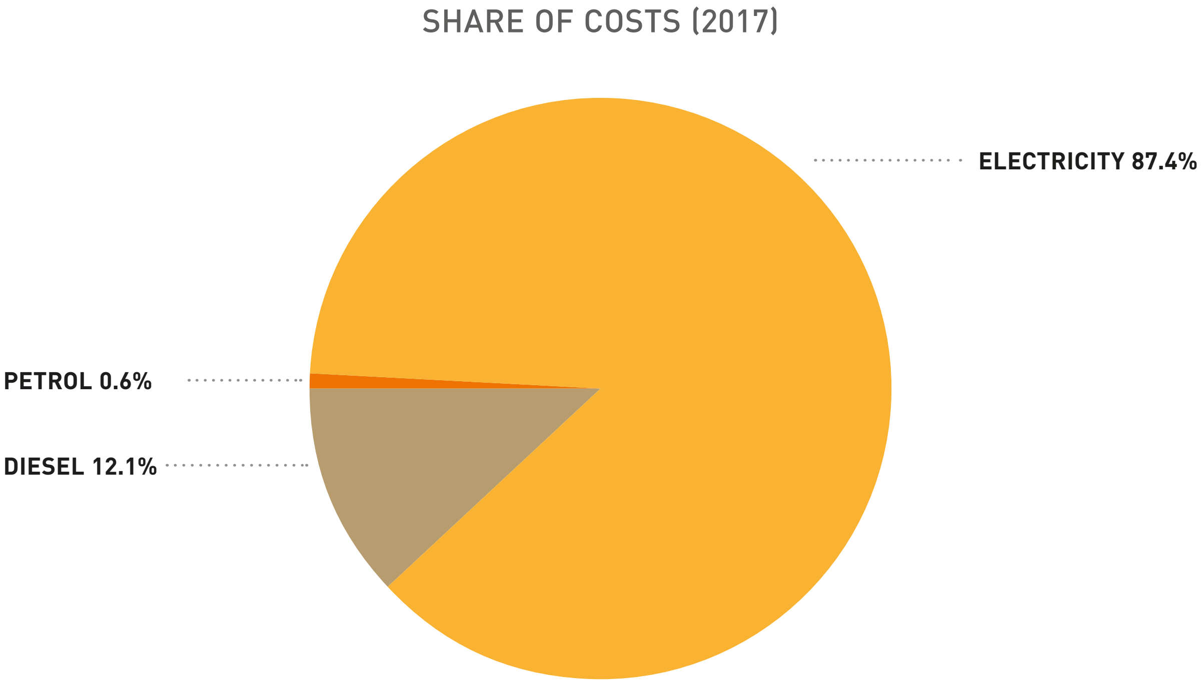


Figure 9 - Share of Consumption

In 2017, the largest share of energy source was electricity, followed by diesel and then gasoline. In terms of energy costs, the largest share was also electricity, then diesel, then gasoline.

Jill can already draw one conclusion: electricity is worth to be analysed more deeply because it represents the largest cost factor.

Going deeper, Jill can also look at the development of energy consumption in the past years:

Electricity (without peak and rective power): Consumption and Costs

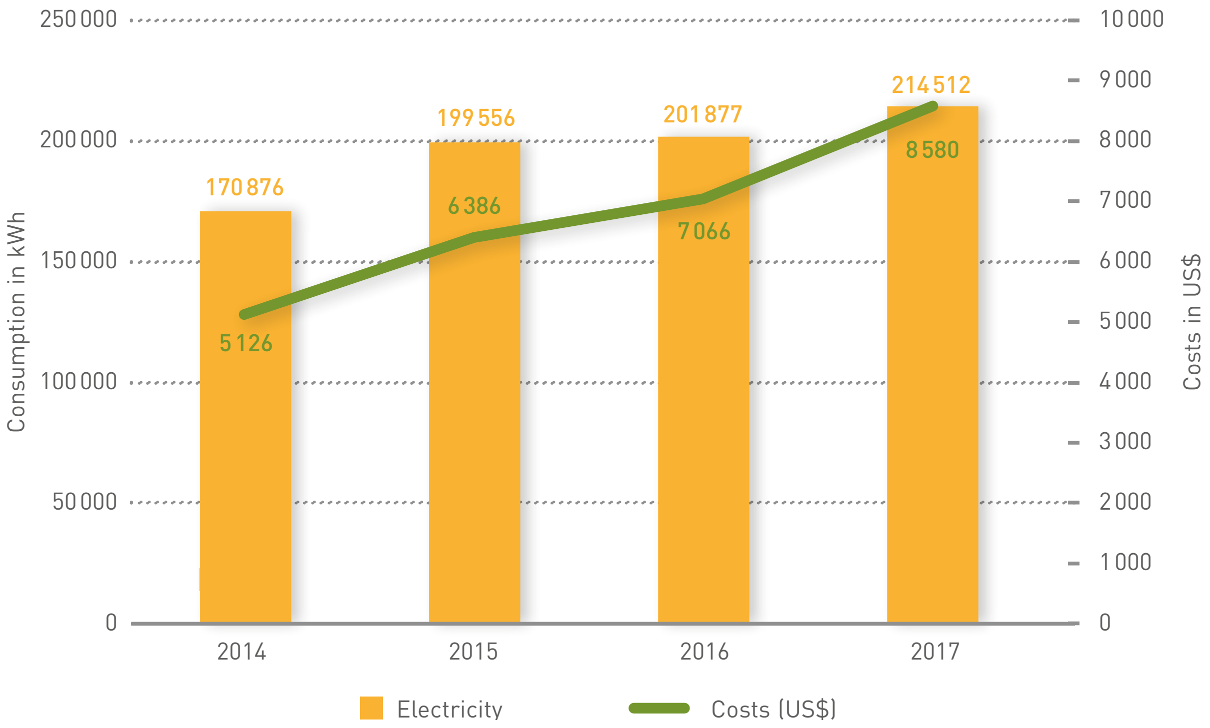


Figure 10 - Electricity: Consumption and Costs

The electricity consumption has increased steadily from 2014 to 2017. Reasons for this are:

- increase in actual consumption, for example caused by more electrical equipment or longer running times of equipment and/or
- deterioration of energy efficiency of electrical equipment (means more energy is wasted)
- increase in electricity tariff from $0.03 in 2014 to $0.04 in 2017.

Based on the data captured so far, Jill decides to investigate further where the energy costs are coming from.

2.3.4.3. Calculate the amount of energy used per equipment

Where is the energy being used?

Significant energy uses are machines, equipment and tools which actually use the input energy- electricity, fuels, heat- to perform work, for example electric motors, water pumps or heat boilers to provide hot water. In Excel-table A3-2 the most important energy uses, their rated power, operating hours and consumption are listed. All in all, a total of at least 80% of the input energy should be accounted for. It is important to distinguish consumers according to their applications (See Chapter 1).

To make the data capturing easier, Excel-tables Spreadsheet A3-3- to A3-9 (annex Excel file) provide lists for the most usual applications. You should monitor the rated power and full-load hours. If necessary, estimate them for small machines, large machines usually have operating time meters. Then calculate the total consumption and allocate this value to consumer groups and specific applications. Use the column 'Notes' to record details on energy saving measures and any necessary renewal or maintenance work identified during the data collection.

Jill wants to know where the energy – particularly the electricity, because it's the highest cost factor – is used. For this, she asks Jack to do an energy use survey of all equipment and machinery. Jack establishes a list of all energy-using equipment:

Table 7: Significant energy uses

Use	Rated Power [kW]	Average load factor [%]	Hours/Day	Days/Year	Hours/Year	Consumption [kWh/a]	Share of Total
Electricity uses							
Ventilation and Air Conditioning	50	40%	14	250	3,500	70,000	33%
Refrigerated storage area	10.7	70%	24	365	8,760	65,612	31%
IT and other electronic office supplies	2	50%	24	365	8,760	8,760	4%
Lighting	15	100%	14	250	3,500	52,500	25%
Small equipment for sorting, grading and packing	1	70%	1	200	200	140	0.1%
Various	5	80%	10	365	3,650	14,600	7%

Heat fuel uses	Rated Power [kW]	Average load factor [%]	Hours/Day	Days/Year	Hours/Year	Consumption [kWh/a]	Share of Total
Brush cutter	1.9	70%	2	200	400	532	73%
Water pumps	1	70%	2	200	400	202	27%
Transport fuels							
Tractor						8,815	69%
Small reefer truck						4,000	31%
Total electricity						**211,612**	92%
Total heat fuel						**734**	0.3%
Total transport						**12,815**	6%
Year	**2017**				**TOTAL ENERGY INPUT**	**229,937**	
Share of total energy input (%)						92%	

Jack gets the rated power in kW from the nameplates on the equipment. For the average load factor, he either used standard values from the equipment manufacturer which he found in the manuals or he discussed it with the machine operator- sometimes, this were some hard discussions but since no machine runs constantly on 100% – except for lighting – the technician believes that the values he used are close enough to reality.

Jill and Jack can now see where the energy is going: about 89% of electricity is going to Ventilation and Air Conditioning, refrigeration and lighting. The rest (4%) is going to IT and small equipment.

For various equipment (7%), the technician did not capture the data because the work would have been too much- it was more important for him to capture the data of the big machines.

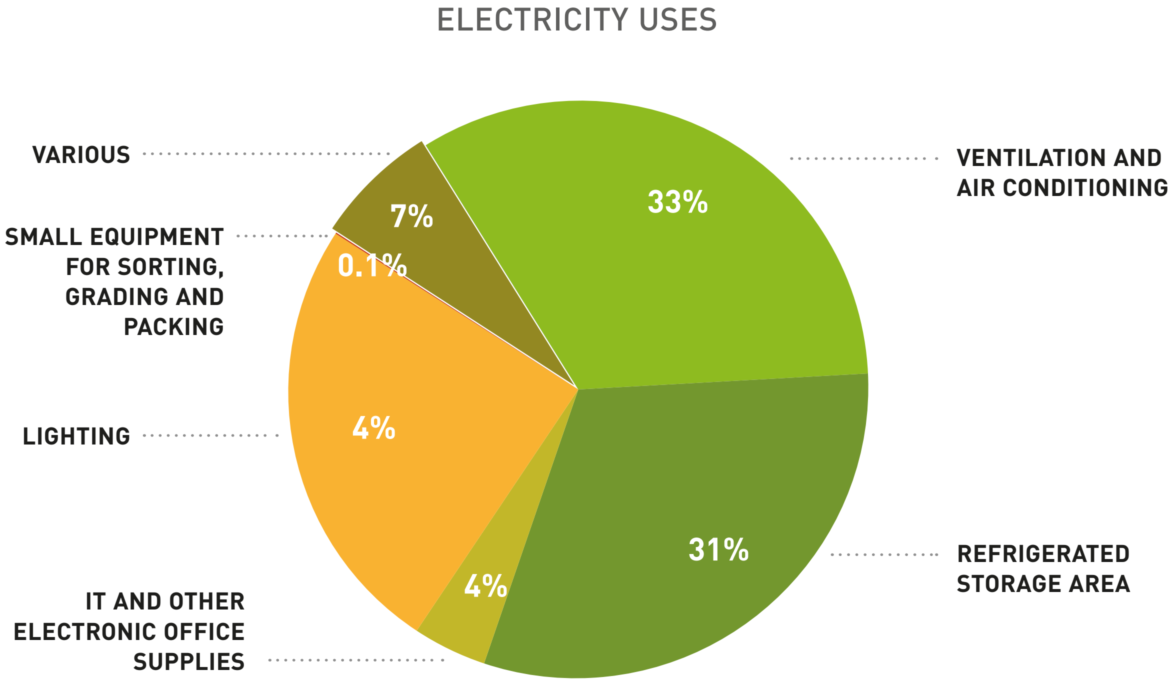


Figure 11 - Electricity uses

The brush cutter uses gasoline to fire a combustion engine, the water pumps use diesel for that. These two machines only represent 0.3% of the total energy input. The tractor and the small reefer truck represent 6% of the total energy input.

2.3.4.4. Identify the Energy performance indicators

How can we track our energy consumption in the future?

For the evaluation of a company's energy consumption, reference values, the so-called energy performance indicators (EnPIs) are essential. For instance, in the case of a brewery, an indicator can be the heating oil consumption per hectolitre of beer. These indicators can differ substantially depending on the type of energy or the characteristics of the company. Typical reference values are production volume, turnover, number of staff, heated surface, transported volume, mileage, etc.

Every company should strive to reduce its specific energy consumption. For expanding companies, benchmark trends are a reliable indicator of energy efficiency, whereas overall energy consumption is not really significant.

Based on the specific energy consumption, the energy situation in a company can be analysed and controlled. In this case, the following points have to be considered.

- Has the specific energy consumption changed? Do we observe a significant increase in energy costs?
- Are the calculations of the specific energy consumption based on correct figures and assumptions?
- If the specific energy consumption has increased: What could be the reason? Which areas have expanded? Has this expansion caused the higher specific energy consumption? Have energy sources been substituted?

- If the specific energy consumption has decreased: Is the decrease due to specific energy saving measures? Have the targets been met? Or has the consumption decreased because energy sources were substituted?
- Where can I find appropriate benchmarks?
    - Ask colleagues for data from a particular sector.
    - Ask plant manufacturers for data.
    - Search in literature (research, magazines);
    - Carry out own calculations.

EnPIs are a perfect tool for monitoring a company's energy consumption. If done regularly- say monthly- one can easily detect deviations from business-as-usual. You can use Excel-table A3-12 for establishing and reporting EnPIs.

Jill and Jack are aware now of how much energy is consumed, how much they spent on energy and where the energy is being used. Also, they know that the energy consumption has increased in the recent years.

This increase in energy can of course be appropriate because the company has produced more (higher production = higher energy consumption). However, they are not sure about this. In order to find out what the increase in energy consumption caused, Jill establishes a set of EnPIs:

Table 8: Energy performance indicators

	Unit	Quantity				Costs [US$]			
Energy		2014	2015	2016	2017	2014	2015	2016	2017
Electricity	kWh	170,876	199,556	201,877	214,512	5,126	6,386	7,066	8,580
Gasoline	kWh	540	522	602	575	994	1,008	1,088	1,185
Diesel	kWh	14,058	13,860	14,355	14,850	48	47	56	55
EnPI Energy consumption	[kWh/ ton]	**5,299**	**6,113**	**6,195**	**6,570**				
EnPI Energy costs	[US$/ ton]					**176**	**213**	**235**	**281**
Reference values									
Value			**Unit**	**2014**	**2015**	**2016**	**2017**		
Number of employees			persons	7	7	7	7		

		2014	2015	2016	2017
Number of employees	persons	7	7	7	7
Farm area	ha	5	5	5	5
Working days per year	d	250	250	250	250
Production quantity	tons	35	35	35	35

Jill decides to reference their energy consumption to their actual production quantity. In order to see other eventual differences that might have caused the energy increase, they also list their number of staff, farm area and working days per year.

Jill finds that the production quantity has neither increased nor decreased in recent years – it was stable at 35 tons. Nevertheless, as they already know, the energy consumption and energy costs increased:

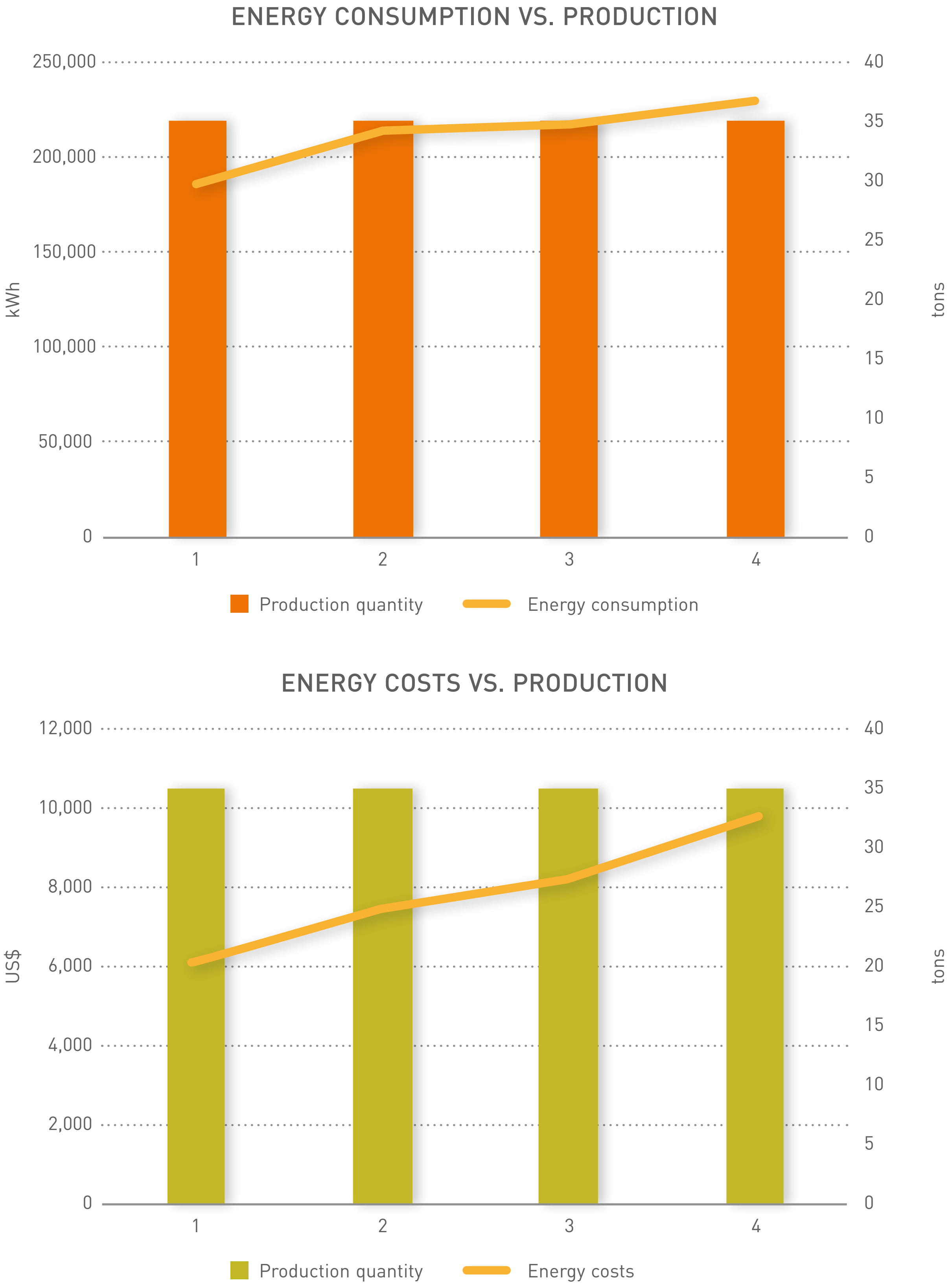
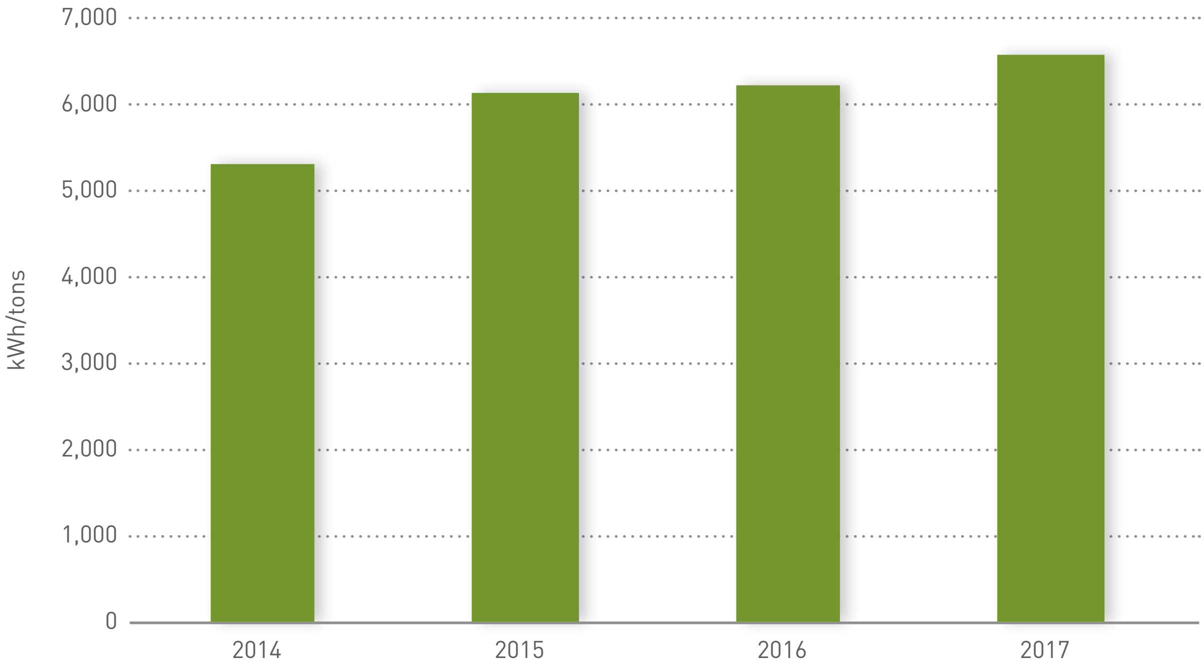


Figure 12 - Energy consumption vs. Production

Jill uses the Excel table to calculates two important EnPIs:

- Energy consumption vs. production in kWh/tons and
- Energy costs vs. production in US$/tons


ENPI ENERGY CONSUMPTION

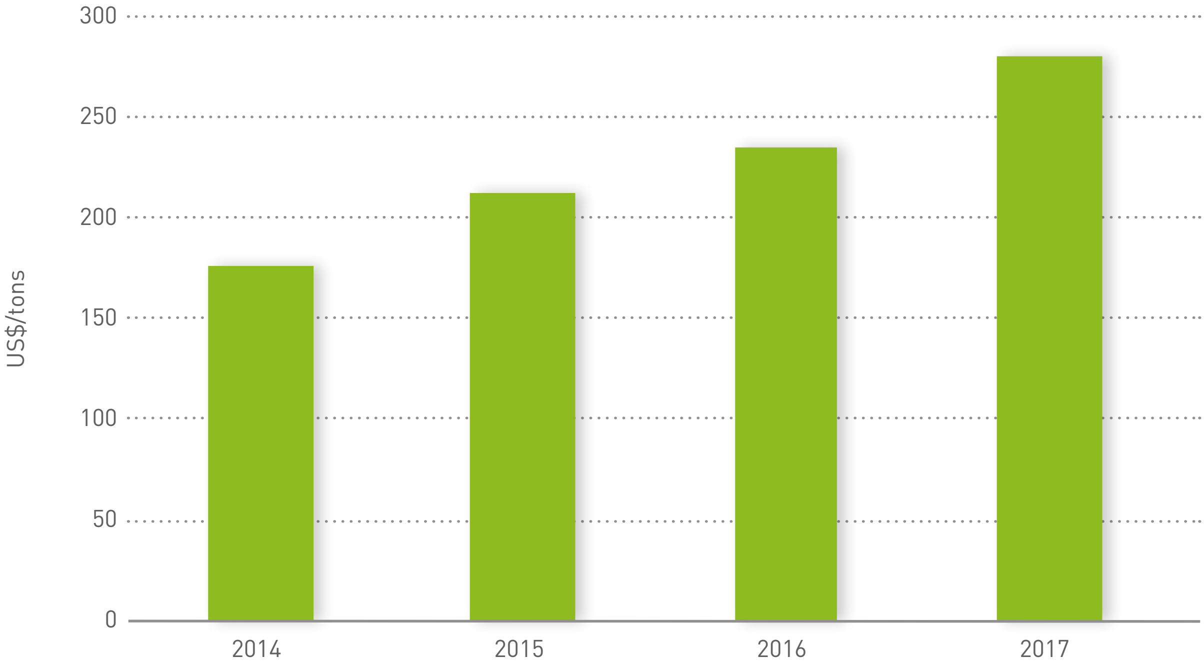

ENPI ENERGY COSTS

Figure 13 - EnPI Energy Consumption

The EnPI Energy consumption increased from 5,299kWh/ton to 6,570kWh/ton despite a stable production quantity. In 2014, the company spent $176 to produce one ton of beans, in 2017 they spent $281 for one ton. That is an increase of 47% over four years!

Jill and Jack are surprised by this and one question comes into their mind: how can we reduce our energy costs?

2.3.4.5. Draft an energy action plan

How can we reduce our energy costs?

As mentioned before, it is important to record and document the energy data of equipment and machinery. Based on the collected data, their respective energy costs can be calculated and allocated to the individual consumers. In this way, the concerned departments can determine the saving potential.

Suppliers often provide reference values of energy consumption for plants and equipment (e.g. efficiency of boilers, energy consumption of refrigerating equipment, etc.). By comparing these data to the data you have collected, you can determine whether your machine runs below or above the rated efficiency. With machines, for instance, which are more than five or ten years old considerable amounts of energy can be saved by installing new microelectronics and sensor technology (e.g.: frequency converters for speed control).

Based on the consumer structure, energy-saving measures can be prioritized and purchasing guidelines can be established. Potential energy efficiency measures (EEMs) should be documented in form of an energy action plan, see Excel-table A3-0.

Jack wants to know how energy efficient the equipment actually is and how energy costs can be reduced. For this, he starts with the biggest "energy guzzlers": as we have seen before, electricity is the largest share of energy costs. The biggest electrical uses are:

- ventilation and air condition (33%)
- refrigeration (31%) and
- lighting (25%).

So, Jack starts with the cold room. It has 20m^2 and cold air is supplied by a central AC-unit with 10.7kW electrical power. The cold room temperature setting is 2°C. The AC unit is fairly new as it was installed only two years ago.

Jack has a good impression of the efficiency of the AC unit- however, he thinks that the temperature setting of 2°C might be unnecessary low. Usually, the optimum storage temperature for their kind of beans is 7°C. Since he has learned that an increase in cooling temperature of only 1°C gives an electrical energy saving of 4%, he wants to increase the set point temperature from 2°C to 7°C.

In total, that would give an energy saving of 5°C x 4% = 20% of the consumption of the AC unit. As Jack has found out earlier, the consumption of the AC unit is 65,612kWh per year. 20% of it would be an energy saving of 13,122kWh per year. With an electricity tariff of $0.04/kWh, this would lead to an energy cost saving of $524 per year- for free, because no investment is needed for that!

Jack is so happy that he found his first energy saving that he continues with the "investigation" of the other energy guzzlers. Next, he has a look at the lighting system of the packing storage area, about 300m². The area is lit by 20 metal-halide-lamps of 450W each. Jack knows that the lamps are old, he suspects them to be at least 20 years in use. The light they give is rather mellow and not suitable anymore for a working area. Jack would like to go for the latest, energy saving LED-technology. However, he is not sure whether such an investment will pay off in time.

The installed power of the lamps is 20 x 450W = 9,000W or 9kW. The yearly running time is 3,500 hours. Thus, the annual electricity consumption is 9kW x 3,500h = 31,500kWh. With the electricity tariff the yearly energy costs are $1,260.

Jack knows that he can replace the old metal-halide lamps with LEDs. Usually, a 450W lamp can be replaced by a 120W LED-lamp to have the same amount of light in the working area as before. Thus, the LED lamps would have only 2.4kW power and consume only 8,400kWh per year. Their energy costs would be $336 which would be a cost saving of $924 per year (Table 9).

Table 9: Total power and energy costs old versus new lamps

	Qty	Power (W)	Total power (kW)	Running time (hrs)	Energy (kWh)	Tariff ($)	Electr. costs ($)
Old lamps	20	450	9	3500	31500	0,04	1260
New lamps	20	120	2,4	3500	8400	0,04	336
						Saving	924

Table 10: Maintenance old versus new lamps

	Qty replaced yearly	Price ($)	Maint. cost ($)
Old lamps	4	150	600
New lamps	0	350	0
		Saving	600

However, energy is only one cost factor in lighting. Jack has observed that he needs to replace four lamps a year due to age. One of the old lamps costs $150. With LED, the lifetime is more than double than that of the old lamps (see Table 10).

Altogether, the yearly cost saving would be $1,524- an 82% reduction! (see Table 11) Jack can calculate the simple payback time: the cost for one LED lamp is $350 which would make an investment including installation of $7,000. The payback time is investment divided by yearly savings, SPT = $7,000/$1,524 = 4.6 years (see Table 12). In shortly under five years, the investment would pay back and the company would save. Considering a lifetime of the LED lamps of more than six years in this case, this is an investment that is worthwhile to do. (See Chapter 1 for more information on pay-back time)

Table 11: Total cost saving

	Total energy (kWh)	Total costs ($)
Old lamps	31,500	1,860
New lamps	8,500	336
Savings	23,100	1,524
Percentage	73%	82%

Table 12: Payback time

	Qty	Price ($)	Installation ($)	Investment ($)	Savings ($)
New lamps	20	350	(incl. In price)	7,000	1,524
				Payback time (yrs)	4,6

Another topic that came up during the investigation was solar energy. Jack and Jill had heard from the local news that there is a grant programme available from the regional government. The article said that farmers and other small businesses can receive a 30% grant if they install solar energy for electricity production. With the prices for solar equipment have fallen drastically in recent years, this is just another pro-argument for going solar. Thus, Jack and Jill consider the benefits of solar electricity:

- It's a 'green' technology – no emissions, no fuel needed, no noise, no fume.
- The sun does not send a bill for its energy delivery – it comes free with the sunlight.
- Because there are no moving parts like in a generator, maintenance and operation of the solar system is almost free of cost (and trouble).
- It makes the business a little more independent from utilities and fuel suppliers.
- It makes particularly independent from inflation that causes increase in utility prices for electricity and fuel.
- Solar energy is particularly successful in places where there are long sunshine hours and plenty of space- a farm is an ideal spot for that.

Solar energy can be used for a variety of applications in a farming business: providing electricity, solar water pumping instead of using diesel-pumps, solar drying of fruits, nuts etc., solar refrigeration, solar heating and many more.

Jack and Jill wonder how much solar electricity is feasible for their farm and how much it would cost. Factors that could impact their decision include:

- How much money do we have to invest in a solar electric system?
- How much space do we have available for development?
- Does our utility provider have capacity limits restricting the size of my system?
- Do we have future plans for expansion on the farm that will add electric demanding equipment or buildings?
- Is our electric usage fairly consistent or variable?
- Do we need to provide electricity during night?
- Can I reduce my electrical demand by deploying energy efficiency?

Although one may want to generate all of the electricity with the sun, many solar electric system owners begin with a small system to supplement their main supply of electricity. A small system means fewer upfront costs and the ability to gauge how much generating capacity is necessary. In addition, generating a fraction of your usage is more economical on a kWh basis than generating closer to 100% of your usage.

Jack and Jill decide to go for a simple, small system first to get to know the technology and see if the promised benefits will translate into reality. Luckily, the government programme establishes contact to a solar expert company nearby. After his visit to the farm, the expert proposes to use the electricity to cover parts of the office demand for electricity. This demand is a pretty stable during the day. As we know from Table 7, the demand is 8,760 kWh per year. The easiest way would be to cover the lights and computers since they only run during day when the sun shines. Their demand sums up to 3,700 kWh per year. However, Jack reckons he can save about 10% of this by more efficient utilization of the office, e.g. by turning off lights more often. Thus, the required demand comes down to 3,330 kWh.

With this figure equipped, the expert can do his job of providing an offer for the solar system. The steps for estimating system properties are:

Table 13: Estimating a solar electrical system

Step	Data	Calculation
1	Identify annual kWh to be powered by the solar system	3,700 kWh/y
2	Subtract kWh reduced by conducting an Energy Audit	Estimation: 10% reduce; 3,700 - 370 = 3,330 kWh/y
3	Find solar radiation at the location	For Paramaribo, Suriname it is 1,600 kWh/y/kW
4	Divide by kWh/y/kW	3,330 (kWh/y)/ 1,600 (kWh/y/kW) = 2.08 kW
5	Multiply by 1.2 to cover system inefficiencies	2,08 kW x 1.2 = 2,50 kW electrical peak power
6	Select solar panels and note the panel size	The expert selected 250 W panels
7	Divide by the kW size of each solar panel	2500 W/ 250 W = 10 panels
8	Calculate the needed space to install the solar panels	Approximate 10 m^2 for every kW; 2.5 kW * 10 m^2 = 25 m^2 area needed

This is only a very basic estimation; the expert will have done it with appropriate modelling software.

The expert also provides Jack and Jill with a proper financial analysis. He calculates the system cost with $4,465. That is $1,785 per kW; minus the 30% grant, the investment is $3,125.

Table 14: Market prices for solar electric equipment (Source: NREL, 2017)

	Utility scale >1 MW	Commercial >100 kW	Residential <100 kW
Incl. panels, inverter, BOS hardware, install labour (excl. land, tax, overheads)	$800/kW	$1,250/kW	$1,800/kW

The dynamic payback time of the system would be 11 years. Since solar panels have a warranty time of at least 25 years, this is a good investment to start with. Depending on the development of electricity and fuel prices, the payback time might even be much less. Also, prices for solar panels decrease the bigger the size of the system is.

Jack and his colleagues have found some more opportunities to save energy and costs. He documents them in his energy action plan for monitoring and further planning:

Table 15: Energy action plan

Item	Action	Responsible	Deadline	Investment (US$)	Status	Savings			Amorti-sation [years]
						ENERGY (kWh)	CO_2 (tons)	PROFIT (US$)	
Refrigeration	Increase the set point temperature from 2 °C to 7 °C in the cold room.	Jack	May 2017	0	100%	13,122	7.4	524	**0.0**
Lighting	Change 20 old metal-halide-lamps to LED lamps.	Jack	Oct. 2017	6,000	75%	23,100	10	1,524	**3.9**
Ventilation	Retrofit the two 7.5kW-fan motors with variable speed drive (VSD)	Jack	Dec. 2017	3,000	50%	15,000	8	600	**5.0**
Transport	Investigate if the bean farmer cooperative can provide one new delivery truck for all our small farms so that we can sell our reefer truck and save the fuel	Jill	1 Feb. 2018	0	0%	4,000	5	316	**0.0**

Item	Action	Responsible	Deadline	Investment (US$)	Status	Savings			Amorti-sation [years]
						ENERGY (kWh)	CO_2 (tons)	PROFIT (US$)	
Transport	Our tractor is almost 20 years old and too small for expansion- request an offer from ‘Brunos Tractor Sales & Repair’ for a new, bigger tractor (maybe it has less fuel consumption?!)	Jill	15 Feb. 2018	cannot say yet	0%	??	??	?? If any?	**?**
Renewable energy	‘Smith Solar Works’ made us a proposal for using a 2.5kW solar PV system to power parts the IT and office equipment- we can get a 30% grant from this government ‘solar for farms’-programme!	Jill	30 March 2018	3,125	50%	no saving	2.6	285	**11**
Awareness	There are these nice stickers available for download which say ‘Lights out’ and ‘Keep doors closed’ and other things to save energy- we should put them for all staff to remember to be energy-conscious!	Jack	1 Jan. 2018	50	0%	2,000	1	200	**0.3**
			Total	12,175		57,222	37	3,664	

2.3.4.6. Formulate the Energy objectives & monitor the energy consumption

Where do we want to go- and are we on track?

Based on identified opportunities for improvements, an organisation can now identify realistic energy objectives and procedures how to follow up with these objectives, what is called 'monitoring'.

Energy objectives are describing an overall aim but should be quantified and time scaled. Energy objectives are likely to arise from the energy action plan but might originate from other sources, too. The objectives should be focused on priority areas for reducing energy consumption and improving energy efficiency.

An easy way to set an energy objective is to set a target for an EnPI say to lower specific energy consumption for producing one ton of product over time.

Monitoring means for example checking if the energy consumption is reducing as planned but also, if the means are available for this. It also means to regularly check the operations and energy uses for efficiency. More intensive energy operations should be monitored more regularly simply because more is at stake. Monitoring energy use is vital because “only what is measured can be managed”.

Jack and Jill’s plans for the future of their farm include expanding the production to be able to export their beans. Since they know now the cost of energy- and the value of energy savings- they want to expand with minimal energy consumption increase as possible. Based on the above energy action plan, they decide to invest in the following energy saving measures:

- Increase the set point temperature from 2 to 7 °C in the cold room.
- Change 20 old metal-halide-lamps to LED lamps.
- Retrofit the two 7.5kW-fan motors with variable speed drive (VSD).
- Install 2.5kW solar PV system to power the IT and office equipment.
- Put stickers to save energy.

These measures alone will generate 53,222kWh in energy savings and $3,348 in energy cost savings per year. This is 23% of total energy consumption in 2017 respectively 34% of total energy costs in 2017.

By the time the above measures are implemented, the total energy consumption will increase about 10% due to the following circumstances:

- a bigger tractor is needed;
- the farm land will increase and thus a bigger water pump is needed.

Having the expansion in mind, they set the following objectives using their EnPIs:

Table 16: Energy objectives

		2014	2015	2016	2017	2018	2019	2020
EnPI Energy consumption	[kWh/ ton]	5,299	6,113	6,195	6,570	6,570	6,000	5,500
Reduction to baseline year 2017	%					0%	10%	15%
EnPI Energy costs	[US$/ ton]	176	213	235	281	281	255	225
Reduction to baseline year 2017	%					0%	10%	20%
Production quantity	tons	35	35	35	35	35	40	40

Thus, the energy objectives of the Dushi small beans farm are as follows:

1. Reduce specific energy consumption in kWh per ton by 15% until 2020 (from 2017)
2. Reduce specific energy costs in US$ per ton by 20% until 2020 (from 2017)

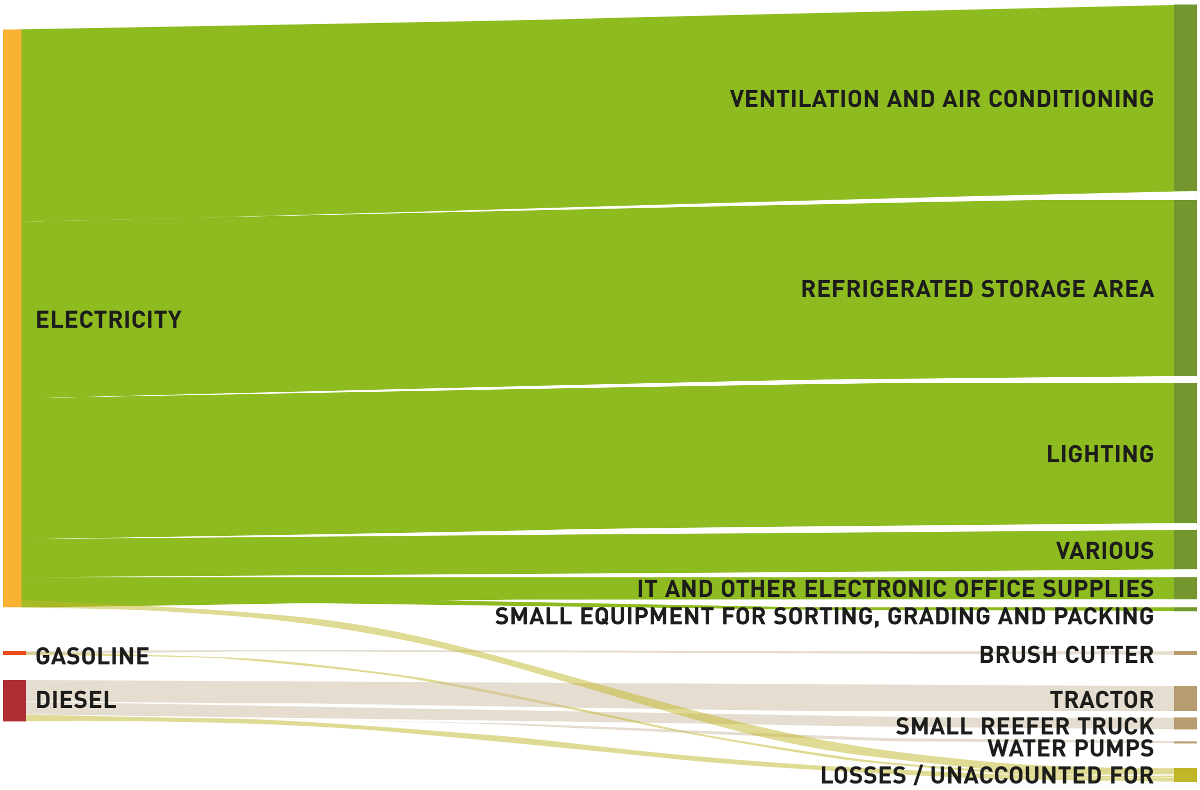
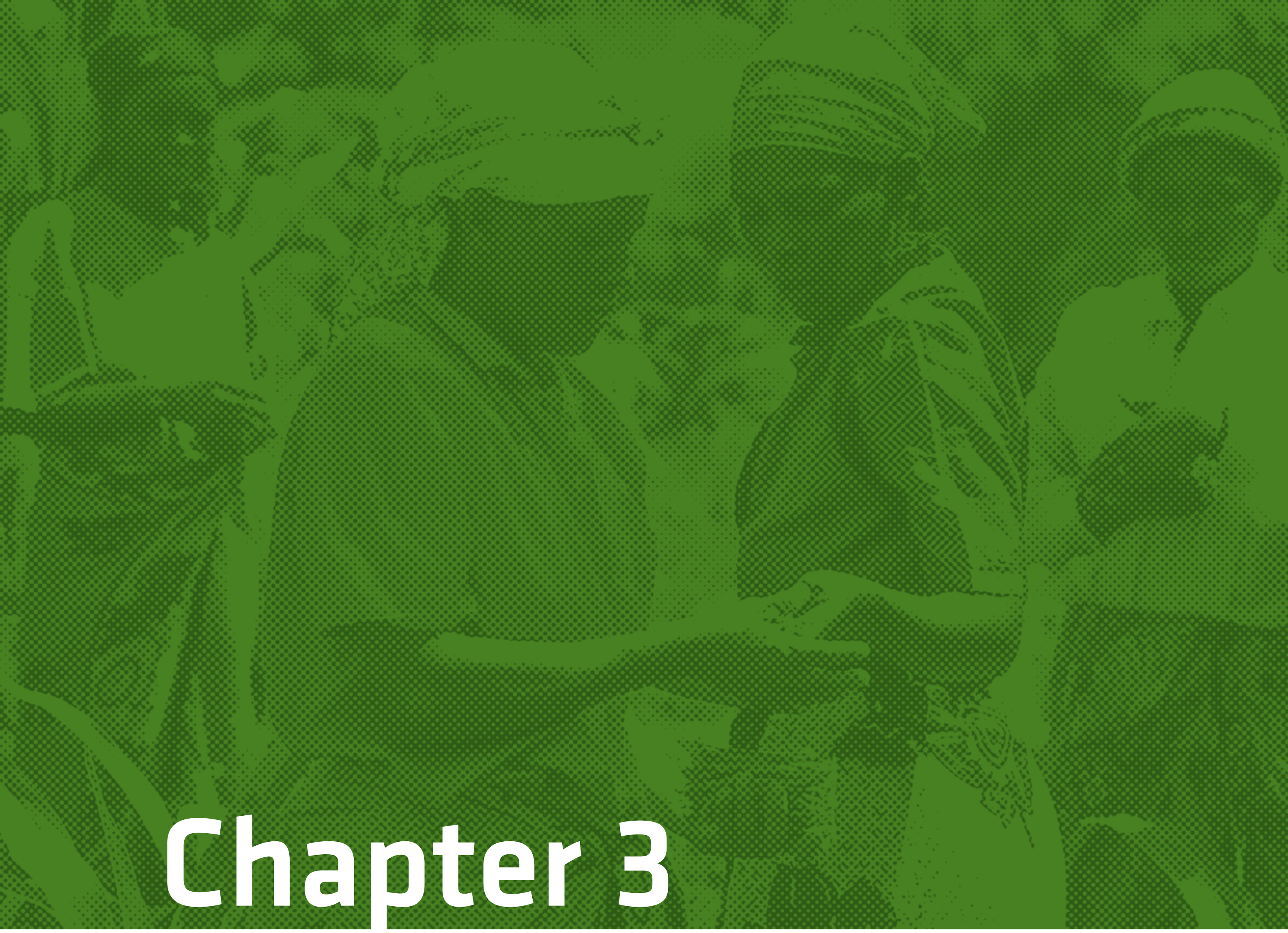


Figure 14 - Dushi Energy Balance map

In the above schematic, a so-called 'energy flow diagram', the results of the energy analysis (steps 1 and 2) are visualized. Such a diagram can be produced more simply by drawing it by hand on a paper or using a common software like Microsoft Draw or Word. This one here shows not only **where** the energy is going to (e.g. the electricity is being used in ventilation and air-conditioning, refrigeration, lighting and so on) but also **how much** is being used where. The width of the flows represents the amount of energy in kWh. Thus, it is visible that the largest amount of energy consumed is electricity, the second largest the energy bound in the diesel fuel and the smallest portion is from gasoline. On the other side of the diagram, we can see that the largest amount of energy goes into the ventilation and air-conditioning, followed by refrigeration and lighting. The tractor consumes most of the diesel energy. Also, we can calculate and represent losses of energy, e.g. waste heat as it occurs when burning diesel fuel in a combustion engine. Moreover, we can show energy flows that are unaccounted for, i.e. the gap in the total energy input (Table 6) and energy uses we can account for (Table 7).



Chapter 3

Energy transition, techniques of management and production of renewable energy

LEARNING OBJECTIVES

At the end of this chapter, the learner should be able to:

- Know the principle of energy transition.
- Know the different types of renewable energy available technologies.
- Know the available tools for decision-making and how to use them.
- Make choices/advise operators on the type of technology to be adopted with a purpose to reducing energy consumption.

3.1. ENERGY TRANSITION

3.1.1. Policies, governance and funding opportunities that support energy transition in ACP countries

The previous chapters focused on two factors that impact on all sized actors involved in agro-food chains. The first has been that of understanding how agriculture enterprises use energy both directly in the form of fuel (gasoline, diesel, natural gas) and electricity and indirectly through use of energy-intensive-inputs, such as fertilizers and pesticides, as well how energy is lost when it is converted from one form to another. The second is the fact that farmers really need to embrace new ideas which are targeted at using energy in an efficient way for a number of reasons: reduce GHG emissions, ensure long-term food security and cut operating costs and increase profits behind and beyond the farm gate. Before these co-benefits are realised an **energy transition** i.e. **a long-term structural change in an energy system must take place** (Smil, 2017). This entails making a change from a purely fossil-based energy system or, systems where energy losses are considered to be high, to a more **sustainable energy** system.

In most of the ACP countries, agriculture and related agro-food activities are at the heart of rural economies, with a large percentage of households employed in harvesting, agro-processing, and the transport and marketing of produce. Yet, these rural communities are still struggling with the lack of access and affordability of resources, and they can be limited to producing low-quality goods with little variety (IRENA, 2016). Although the integration of land use for agriculture and energy purposes is growing, barriers to greater RE deployment in rural areas include high capital costs, lack of available financing, remoteness from energy demand (including access to electricity and gas grids), competition for land use, transport constraints, water supply limitations, and lack of skills and knowledge on the part of landowners and managers on how to make an energy transition (IPCC 2012).

To overcome this challenge there are various policy and governance related initiatives that have been put into place in the Caribbean and the Pacific to deal with this situation that were highlighted in Chapter 1. Also, the ACP-EU Energy Facility has been instrumental in funding policy and governance initiatives across the African continent. These actions are helping to introduce RE technologies in rural areas with the aim of boosting agricultural productivity, reducing food losses and food imports, eliminating malnutrition and increasing resilience to climate variability. The ACP-EU Energy Facility has aided access to energy services in rural and peri-urban areas and improved energy governance and capacity development for African ACP countries through:

- The West African Power Pool (WAPP further information available at http://www.ecowapp.org/) which is a specialized institution under the Economic Community of West African States (ECOWAS). Objectives of WAPP can be summarized as the provision of greater access to energy at lower cost and with higher reliability. In addition, WAPP's role is to coordinate infrastructure development and facilitate energy trade in Western Africa. There are 104 countries in the WAPP. The ACP-EU Energy Facility has contributed funding both for cross-border infrastructural projects, especially for transmission, and for institutional support. (For further information: www.ecowapp.org).
- The CAPP (Central Africa Power Pool further information available at https://www.peac-sig.org/index.php/en/) is a specialised body of the ECCAS (Economic Community of Central African States) in charge of implementing and coordinating the energy policy, infrastructure expansion, as well as establishing the legal, technical and commercial conditions to increase investments and electricity exchanges in the sub-region. The CAPP is formed by power companies from: Angola, DR Congo, Congo/Brazzaville, Gabon, Equatorial Guinea, Sao Tome et Principe, Cameroon, Chad, Rwanda and Burundi. The Energy Facility supports the following priority actions: advice on network operation, on development of regional markets and regulatory bodies, and support to pilot programmes for cross-border electrification. (For further information: https://www.peac-sig.org/index.php/en/).
- Membership of the East Africa Power Pool (EAPP further information available at http://eappool.org/about-eapp/) comprises public or concessionary utilities/companies in charge of power generation, transmission and/ or distribution in Eastern African countries. The EAPP was established in February 2005 when the Ministers responsible for energy in 7 countries in the region (Egypt, Sudan, Ethiopia, Kenya, Rwanda, Burundi and the Democratic Republic of Congo) signed the Inter-Governmental Memorandum of Understanding creating the pool. The headquarters are in Addis Ababa, Ethiopia. (For further information: http://eappool.org/).
- The Southern African Power Pool (SAPP further information available at http://www.sapp.co.zw/), with its headquarter in Harare, was created in April 1995 through the SADC treaty, through which the member countries agreed to optimise the use of available energy resources in the region and support one another during power emergencies. At the time of creation, the SADC governments agreed to allow their national power utilities to enter into the necessary agreements that regulate the establishment and operation of the SAPP. SAPP membership was therefore restricted to national power utilities of the SADC member states. The Priority Actions financed from the Energy Facility for the SAPP are mainly capacity building for network operations, system planning and promotion of public-private partnerships. (For more information: www.sapp.co.zw).

It needs to be noted that ISO/IEC-13273 guides the development of activities related to energy and that deal with energy efficiency and renewable energy sources. This International Standard is a horizontal standard in accordance with IEC Guide 108.

This International Standard addresses the fundamental principles and concepts of energy efficiency and energy management terminology, which is relevant to a number of technical committees, with the goal of improving coherence and common characteristics for energy terms. This International Standard does not address terms specific to topics such as environmental sustainability or nuclear energy but rather transverse energy terminology. This ISO is meant more for regulatory bodies that are engaged in developing standards for energy efficiency and renewable energy sources. (https://www.iso.org/standard/62606.html)

3.1.2. The benefits associated with an energy transition?

It has been pointed out both in Chapter 1 and Chapter 2 that depleting stocks of fossil fuels and the impact that the use of fuels has had on global warming are the two factors that are driving both countries with high and low GDPs to base their economies on more sustainable energy systems. Countries within the regions covered by the ACP funding programs are mostly signatories to the ACP Cotonou Partnership Agreement and as such have an obligation to ensure that agricultural activity at country level is restructured as much as national budgets can support to follow this move. Examples of how an energy transition has taken place in some agricultural enterprises from ACP countries were highlighted in the previous chapters as points of reference.

Given all of the foregoing, for those involved in agro-food chains, the processes involved with making an energy transition might not only help to reduce GHG emissions and energy losses, but also benefit individual enterprises to:

- Develop their operations in a far more sustainable manner,
- Improve both their own health and that of their employees, and
- Help to generate local employment opportunities.

which are just some of the potential benefits. Other benefits that relate to productivity and output both behind and beyond the farm gate appear in the table below.

Table 1: Advantages of using RE along the agro-food chain
Adapted from IRENA, 2013.

Increased productivity due to	Increased output due to	Activity in the agro-food chain	Example on income generation
Increased output that can be sold	Increased yields quantity and quality	Pumping for irrigation	Irrigation projects in Tanzania were able to achieve higher incomes through increased agricultural productivity. One irrigation project triggered the establishment of a tree nursery producing seedlings that are sold in the region and beyond to farmer groups, companies and individuals (Terrapon-Pfaff *et al.* 2014).
	Reduced waste through improved storage	Drying	A solar dryer in Malawi can dry 80kg. of maze grain per batch and has a payback period of less than one year if surplus grain is dried and sold in the market (World Bank *et al.*, 2011).
		Refrigeration	Off-grid refrigeration can save around 35% to 55% of food wasted on the supply chain due to the lack of refrigeration (Fridgehub n.d.).
Reduced time	Reduced time and cost of agro-processing	Agro-processing	A rice thresher in sub-Saharan Africa produces 6 tonnes of rice/day compared to 1 tonne/day using a manual thresher (World Bank *et al.* 2011).
Reduced cost	Reduced spending on traditional fuel	Agro-processing	Savings on annual diesel spending can be realized by introducing improved water mills for grain processing.

3.1.3. Renewable energy (RE) technologies for agro-food chains

As explained in Chapter 1, Renewable Energy is energy derived from natural processes (e.g., sunlight, wind, hydrological, geothermal, biomass or tidal sources) that are replenished at a faster rate than they are consumed. We have already demonstrated just how the use of renewable energy, especially in rural remote areas of many low GDP countries, can help farmers to increase agricultural productivity, as well as to earn more money by adding value to their produce. However, the farmer or enterprise owner must be able to choose the appropriate renewable energy source, or the optimum combination of sources. The type of energy source preferred will always depend on the resources available on site and the financial investment involved with this type of energy transition.

The technologies used to harness renewable energy resources and convert them into useful energy forms are called Renewable Energy (RE) technologies. For farmers there are several RE technology solutions available that could be integrated into the agricultural process that can lead to higher energy efficiencies, lower environmental impact and reduced production costs.

RE technologies and energy-efficiency interventions can be at different stages of the agro-food value chain, from production to commercialization as outlined in the figure below.

PRODUCTION	POST HARVEST & STORAGE	PROCESSING	COMMERCIALISATION
• Solar wind powered water pumping • Bio-fuel powered machinery • Solar desalinisation, heating/cooling • Efficiency machinery maintenance • Low-pressure efficient irrigation • Biomass residue energy generation	• Solar geothermal food drying for storage • Solar cooling and refrigeration • Minimized efficient packaging • Food loss reductions • Efficient drying • Improved insulation for cool storage	• Solar, wind, hydro milling, processing, cooking, drying, etc. • Renewable electricity and heating application • Efficient processing for cooking • SMART* integration into existing fossil fuel system	• Biofuel for transportation and distribution • Solar cooling and refrigeration (retail) • Improved efficient infrastructure • Efficient market information through modern ICTS • Capacity building for farmers, traders etc.

Figure 1 - Examples of clean energy in agro-food chains.
Source: Adapted from Power Agriculture MOOC Sustainable Energy for Food available at https://poweringag.org/mooc.

Some of the more readily available and frequently used RE technologies:

- **Hydropower**
- **Wind energy**
- **Energy derived from biomass or bioenergy**
- **Solar energy**
- **Geothermal energy**
- **Tidal energy**

3.1.3.1. Hydropower

Hydropower is the most widely used renewable energy resource because it has significant advantages over other RE resources. The energy is of a higher density, generally cheaper and a more reliable source of RE. Hydropower plants can range in size from Kilowatts (kW) to multi-Gigawatts (GW). Smaller hydropower plants are widely used for rural electrification and can be easily integrated into agri-food chains in many different types of locations.

Principles

Put simply, small-scale hydropower (up to 1MW) work on a simple principle: water from streams or rivers run through a turbine which rotates and turns either a pump or a mill or some similar kind of tool or a generator which in turn produces electricity. A good working knowledge of local water resources is necessary for the use of hydropower so that the appropriate system design can be selected.

Advantages and disadvantages

Advantages:

- Hydropower is a fuelled by water, so it's a clean fuel source. Hydropower doesn't.
- pollute the air like power plants that burn fossil fuels, such as coal or natural gas.
- Hydropower relies on the water cycle, which is driven by the sun, thus it's a
- renewable power source.
- Hydropower is generally available on a needs basis i.e. the flow of water through the turbines to produce electricity is generally on demand.
- Other benefits may include water supply and flood control.

Disadvantages:

- Hydropower can impact water quality and flow.
- Hydropower plants can cause low dissolved oxygen levels in the water, a problem that is harmful to riparian (riverbank) habitats. Depending on the size of the power plant the water may need additional oxygen. Maintaining minimum flows of water downstream of a hydropower installation is also critical for the survival of riparian habitats.
- Hydropower plants can be impacted by periods of drought.
- New hydropower facilities impact the local environment and may compete with other uses for the land.
- Those alternative uses may be more highly valued than electricity generation.
- Humans, flora, and fauna may lose their natural habitat.
  (Further information available at http://www.envirothonpa.org/documents/19bHydropowerAdvantagesandDisadvantages.pdf)

Example

Typically, the main components of a small-scale hydropower system are: the weir where water is raised and diverted from the water source; the forebay where the water is collected and the penstock pipe which transports the water into the powerhouse. The turbine and generator are generally located inside the powerhouse (Figure 2.)

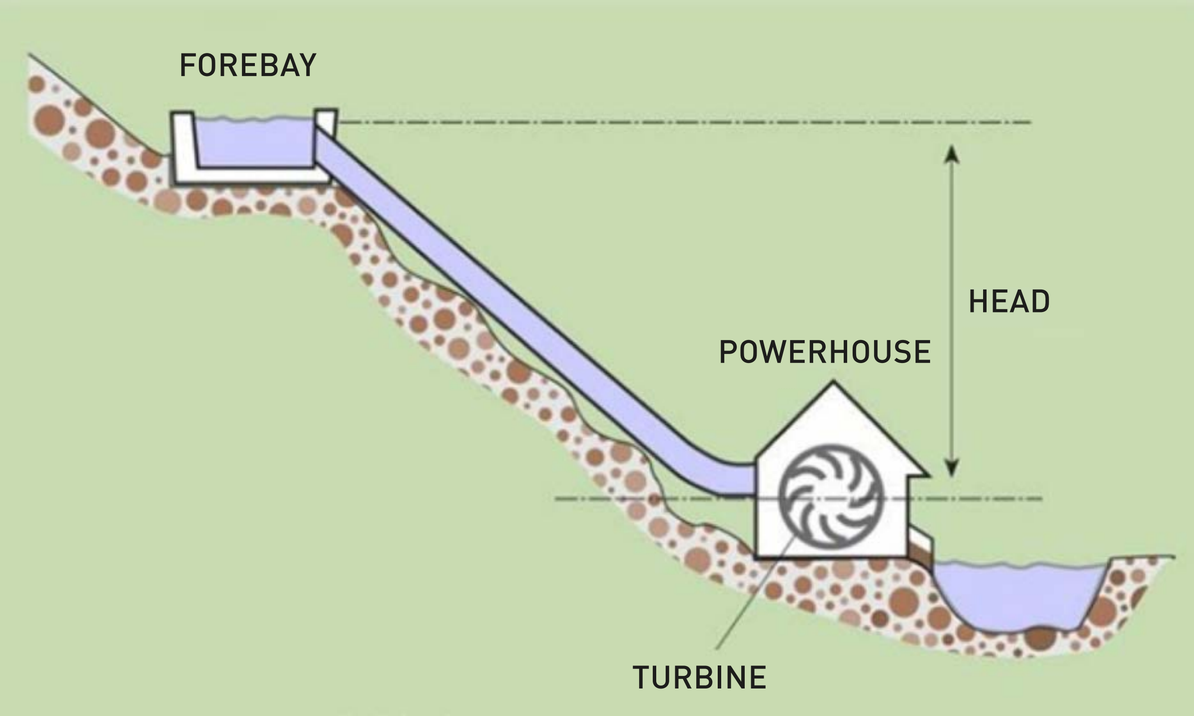


Figure 2 - Schematic of principles of Hydropower Plant – source unknown

3.1.3.2. Wind energy

Principles

Wind, the result of global and local temperature differences, represents another source of renewable energy. The main principle behind wind energy is the transformation of wind flows into rotational movements. This follows the same principle as hydropower systems. The power output of a wind energy system is generally estimated by multiplying the available wind speed by the area swept by the rotor. Similar to hydropower, the rotational force can be used either directly (irrigation pumps, mills etc.) or to drive a generator and produce electricity. Hence, the possibilities for its use in agriculture are plentiful. Of course, the wind does not blow as constantly as a river flows. Therefore, estimating annual energy yield can differ during different seasons or periods (Powering Agriculture: An Energy Grand Challenge for Development available at https://poweringag.org/mooc).

Advantages and disadvantages

Advantages:

- In general, the specific energy costs per kWh generated decreases with increasing size of turbine so smaller turbines are relatively expensive per kW of installed capacity. Micro-wind turbines may be as small as 50 W and generate only about 300 kWh/yr. The electricity is usually stored in batteries so it can be used for small refrigeration units, electric fence charging, lighting, and other low power uses. Small turbines in locations at low wind speeds (4m/s.-5m/s.) could generate up to 1,500 kWh/yr. and save around 0.75 t CO_2-eq if displacing diesel generation. Small turbines of 20 kW and 9m rotor diameter can produce about 20 MWh per year for use on farms, and small agro-food businesses.
- Owing to the above there are no specific land size requirements for wind turbines.
- Wind energy is clean energy (no gas emissions, no particles).
- Installations of wind turbines in the sea are more sustainable because the wind is almost constant.

Technological developments over recent years have resulted in more efficient and more reliable wind turbines. As is the case for several other forms of renewable energy technologies, the benefits of wind turbines include:

- produce no greenhouse gases, though like every manufactured product, they have a carbon footprint;
- can make a significant contribution to a regional electricity supply and to power supply diversification, as well as provide electricity to remote locations off-grid;
- a short lead time between planning and construction as compared to coal, gas, and nuclear- powered projects, though gaining a consent to build a large wind farm with many turbines can take time depending on the perceptions of possible impacts on the local communities;

- flexibility with regard to an increasing energy demand since more turbines can easily be added to an existing wind farm;
- and make use of local resources in terms of labour, capital and materials for towers, roads, and foundations, even if all or parts of the actual wind turbines are imported.

Disadvantages:

- Wind is an intermittent source, so energy production is variable.
- The installation of a wind turbine requires different criteria (frequent winds, sufficient surface, no obstacles to the wind, easy access, proximity to the electricity network, no environmental constraints such as historical monuments, remote site of homes, have the regulatory approvals).
- If the ground surface is not reliably supportive, a minimum of 10 Has. is required in order to install a wind turbine which is significant. Regulations differ on requirements for gaps between turbines.
- Visual and noise pollution, and disturbance of electromagnetic waves (television, radio, portable) are obstacles to the installation of turbines in close proximity to residential areas.
- The cost of production still outweighs the total price of the wind turbine.
- Although this energy is clean, the costs associated with energy generation can be high.
- Although offshore wind turbines are an important asset, the installation of wind turbines should be relatively close to the coast (about 10 km) due to the loss of energy in the electrical conduits.

Example: wind pump for irrigation

Wind pumps or windmills have been used since the 9th century to irrigate fields or to drain the land. Nowadays, the technology is mostly used for pumping solutions in areas without a grid connection but with steady wind conditions. The design installation for a wind pump always depends on the application. Firstly, a distinction has to be made between mechanical and electrical wind pumps.

1. Mechanical wind pumps; the power of wind is directly used to pump water (Figure 3). They are usually more efficient than electrical wind pumps.
2. Electrical wind pumps: the power of wind is used to produce electricity. This electricity feeds an electrical pump which is pumping the water. Their advantage is that pumps can be placed at a distance from the wind turbine.

Figure 3 - Mechanical wind driven water pump –
wind water pump mechanical engineering project VAWT, 2013-2014

Centrifugal pumps generally work better with faster rotating wind turbines while piston and diaphragm pumps work better with slow rotating turbines. In off-grid areas where there is sufficient wind (>5 m/s.) and ground water supply, wind pumps often offer a cost-effective method for domestic and community water supply, small-scale irrigation and livestock water use. (GTZ, 2007).

More recently, electricity generating wind turbines ranging in size from 0.3 kW to 6 MW have become reliable and cost effective. Many rural properties have considerable wind resources, which are still untapped. The amount of electricity generated at a site is related to the wind resources, and the power generated from a turbine is determined by the cube of the wind speed. So, if a wind turbine is located on a site with an excellent mean annual wind speed of 10 m/second (36 km/h - capacity factor around 45%-50%), it will generate around three times as much electricity in a year as if it was located on a good to average site with 7 m/second mean speed (28 km/h - capacity factor around 20%-25%). As a general rule, wind turbines can be competitive where the average wind speed is 5 m/s or greater (18kmh). Usually sites are pre-selected on the basis of a wind atlas, and then validated with on-site wind measurements before development of a wind farm. For grid integration, the variability of the wind can be overcome by having flexible grids when at low to moderate penetration levels (Sims *et al*., 2011).

Water pumping for irrigation consumes a lot of energy, usually by the use of either electricity or diesel for internal combustion engines, to power the pumps. Solar and wind-powered pumps are growing in popularity and should be encouraged where good solar and wind renewable energy resources exist. But first, this is important to manage better its irrigation system. Energy demands for irrigation can be reduced by:

- using gravity supply where possible;
- using efficient designs of electric motors;
- sizing pumping systems to the crop's actual water requirements;
- choosing efficient water pump designs that are correctly matched to suit the task;
- performing pump maintenance regularly;
- using low-head distribution sprinkler systems or drip irrigation in row crops;
- monitoring soil moisture to guide water application rates;
- choosing appropriate and drought resistant crop varieties;
- using weather forecasts when applying water on a rotational basis to different fields;
- varying irrigation rates across a field to match the soil and moisture conditions by using automatic regulation control systems based on Global Positioning Systems (GPS);
- conserving soil moisture after application through mulch, tree shelter belts, etc.;
- maintaining all equipment, water sources, intake screens, etc. in good working condition;
- eliminating system inefficiencies (Sims *et al.* 2015).

Decisions about the choice of wind turbine have to be made upfront, taking into account pumping technology and extraction depth. To select a suitable wind pump, the following information is needed: mean wind speed, total pumping head, daily water requirement, well draw down, water quality and storage requirements.

In summary, it should be noted that the use of wind power in agro-enterprises is still somewhat limited. Because wind turbines do not always produce a constant energy supply there will be times when they produce no electricity at all. Subsequently, on the majority of farms only the mechanical energy from wind-mills is used for water pumping and/or irrigation.

3.1.3.3. Bioenergy

Principles

Bioenergy has a direct linkage to agriculture, because agriculture activities/ processes need energy and energy generating technologies could use the agricultural waste products as resources. Bioenergy resources are generally all energy resources derived from biological origin either in solid, liquid or gaseous form.

Bioenergy is categorized as being either traditional or modern, depending on the history of use and technological complexity:

- **Traditional bioenergy** can include low technology uses such as direct combustion of firewood, charcoal or animal manure for heat generation mainly and light incidentally. Millions of people in developing countries depend on traditional biofuels for their most basic cooking and heating needs (e.g., wood fuels in traditional cook stoves or charcoal). Dependence on traditional bioenergy is associated with low income levels and in some countries, the share of biomass in energy consumption can reach as high as 90%.

- **Modern bioenergy** is generally comprised of electricity heat produced from solid, liquid or gasified biomass and liquid biofuels for transport. Liquid biofuels for transport can be categorized as first generation, produced from starch, sugar or oil containing agricultural crops, or next generation.
- **Next generation (also referred to as second, third or fourth generation)** bioenergy are derived from a variety of biomass materials, e.g., specially grown energy crops, agricultural and forestry residues and other cellulosic material. One of these next generation bio-energies is biofuels like bioethanol and biodiesel, which are currently being produced from first generation or traditional biomass such as maize, other grains, sugar cane, soybeans, cassava, rapeseed, and oil palm.

The major sources of bio-energies appear in the figure below.

Figure 4 - Major sources of biomass

These next generation bioenergy does not only produce biofuels but also electricity and heat through digester systems. The use of both small-scale biomass digesters and larger-scale industrial applications has expanded in recent decades. Generation of electricity from biomass is the largest non-hydro source of renewable energy. It is mainly produced from woods, residues and wastes.

The primary biomass conversion technologies are thermochemical and biological.

1. The **thermo-chemical technologies** include direct combustion of biomass (either alone or co-fired with fossil fuels) and gasification (to producer gas).
2. The **biological technologies** include the anaerobic digestion of biomass to yield biogas which is a mixture primarily of methane and carbon dioxide (Methane is combustible gas and has a heating value of 34.4 MJ/m^3.). Household-scale biomass digesters that operate with local organic wastes like animal manure can generate energy for cooking, heating and lighting in rural areas. Nevertheless, this kind of bioenergy can present technical maintenance and resource challenges i.e. water requirements of digesters (IAASTD EU,2011).

Advantages and disadvantages

Advantages:

- As biomass feedstocks are widely available, bioenergy offers an attractive complement to fossil fuels and thus has potential to alleviate concerns of a geopolitical and energy security nature. Currently about 2.3% of global primary energy is supplied by modern sources of bioenergy such as ethanol, biodiesel, or electricity and industrial process heat.
- Bioenergy technologies are especially useful when waste products from agricultural output or processing can be used to power production.
- Circular economy concepts like cradle-to-cradle often involve bioenergy as a core technology.

Disadvantages:

- Only a small part of globally available biomass can be exploited in an economically, environmentally and socially sustainable way.
- The organic sludge and effluents is often returned to the fields to help mulch and fertilise the soil. The economics of bioenergy, and particularly the positive or negative social and environmental externalities, can vary strongly, depending on the source of biomass, type of conversion, technology and on local circumstances and institutions.
- Many questions still remain unanswered regarding both the development and usage of bioenergy.
- Subsequently research into bio-energies is on-going. Agricultural knowledge, science, and technology (AKST) can play a critical role in improving benefits and reducing potential risks and costs but complementary efforts are needed in the areas of policies, capacity building, and investment to facilitate a socially, economically, and environmentally sustainable food, feed, fibre, and fuels economy. (IAASTD-EU, 2011). Detailed information is available at http://www.etipbioenergy.eu/images/WWF_Sustainable_Bioenergy_final_version.pdf.

Example

Biogas (or solid biofuels) can be used can be used to power water pumps, although it is used more commonly used for heating applications such as cooking. Biogas is ideal for animal farms, as it can serve as a waste management solution for animal manure that can be used as feedstock for the digester. Dual-fuel engines for electricity generation are also used (for both biogas and diesel) to ensure continuous functioning when the production of waste is insufficient (Figure 5).

Biogas production

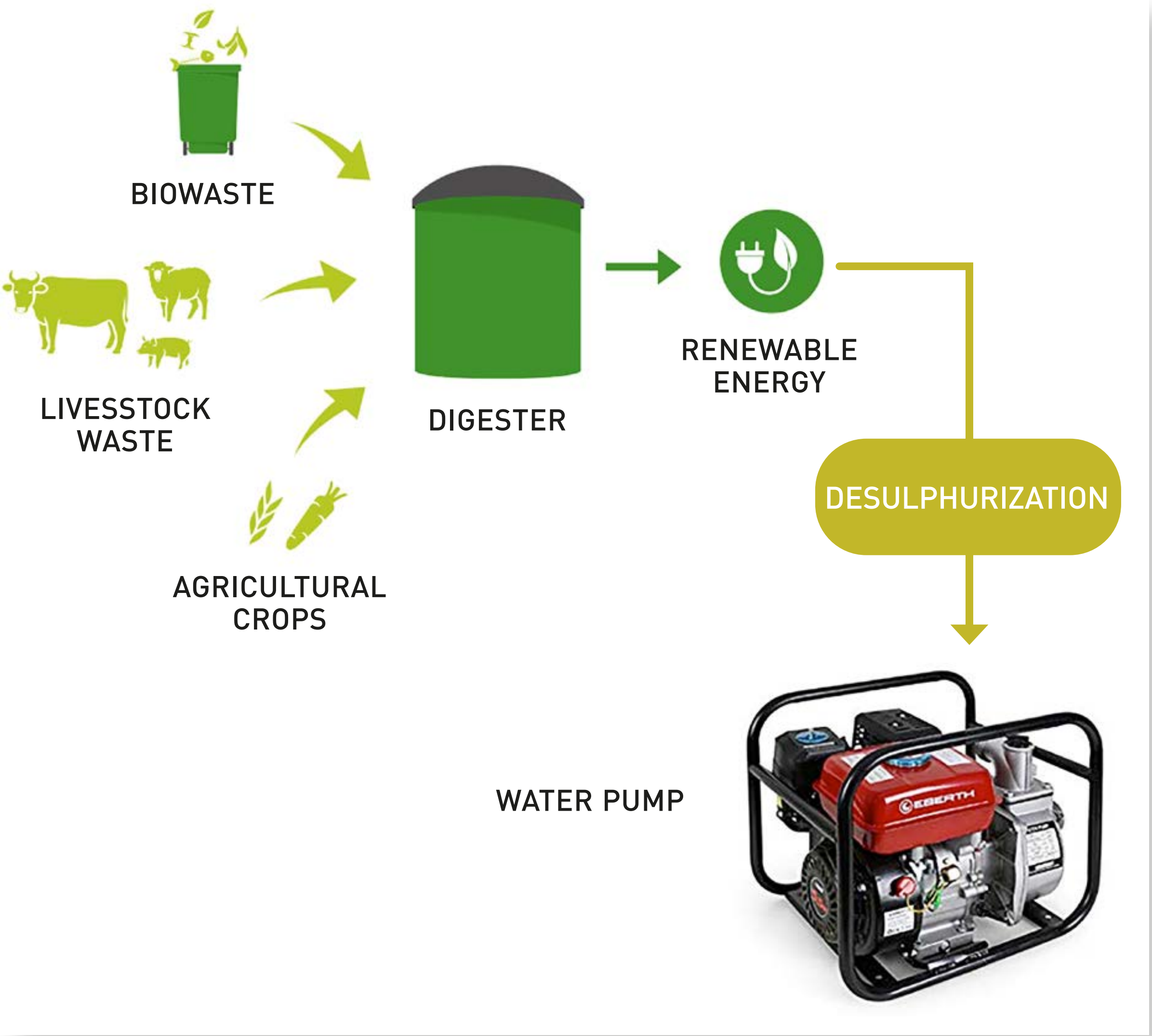


Figure 5 - Biogas driven water pump
Source https://www.jovoto.com/projects/greenpeacechallenge/ideas/30966

3.1.3.4. Solar energy

Principles

There is more solar power that hits the earth every day then the current population can use in a year. Solar energy is a natural form of energy that is produced from the powerful heat and light derived from the sun. The energy is obtained in a form of electromagnetic radiation is turned into usable to power home appliances, car batteries and to light up the house. It is a cheap source of energy since it is obtained from a natural source. Solar energy is very convenient to use during summer season when the sun rays are very strong therefore a lot of solar energy can be generated. Furthermore, it is a clean source of energy since it is created direct from the sun. **Solar energy can have two applications**: Solar thermal and Solar PV.

- **Solar thermal**

Solar thermal technologies are comprised of flat plate collectors for low temperature applications. Examples are solar water heaters, solar air heaters for space heating or drying. The concentrating collectors are used for high temperature application (e.g. power production). In this case, incident solar radiation on a larger surface area is concentrated to a receiver with a smaller surface area using reflecting mirrors. Compared to simple flat plate collector use (refer to examples provided in both Chapter 1 Solar crop dryer in Grenada and simple flat plate collector Chapter 2), these concentrating power plants are more complex. Solar cooking has also been practiced in many countries, though still on a pilot scale. The most common agricultural practice of solar thermal energy use is solar drying.

Different thermal processes in agro industries could benefit of solar thermal, including solar cooling. As outlined in the case study presented in Chapter 1 section 1.1.3 Energy Smart Food Systems (solar powered refrigeration in Angola).

- **Solar photovoltaics (PV)**

Solar PV is one of the most popular renewable energy technologies. Solar PV electricity can be used in versatile ways. Thus far it has only been applied on a large-scale in developed countries, mainly for electricity generation and supply to the grid. In developing countries solar PV has been used in off-grid application, mainly for rural electrification. Off-grid systems work independently, with the help of battery storage systems. The use of PV could be expanded beyond lighting, to different agro-processing activities in many countries, for example powering of small loads used in agro-enterprises, like water pumping or product cooling.

Solar PV is a technology that uses solar cells for energy production. They are made of semi-conductor materials to convert sunlight directly into electricity. When sunlight is absorbed by these materials, it causes electrons to flow through the conductors generating direct electric current (DC).

There are two broad categories of solar cells (also called photovoltaic cells), crystalline (mono and poly) and thin film. The characteristics of these categories are presented in the table below.

Table 2: Characteristics of solar cells

Solar Cell Type		Efficiency-Rate	Advantages	Disadvantages
Crystalline	Monocrystalline	~20%	High efficiency rate; optimised for commercial use; high life-time value	Expensive
	Polycrystalline	~15%	Lower price	Sensitive to high temperatures; lower lifespan & slightly less space efficiency
Thin-Film		~7-10%	Relatively low costs; easy to produce & flexible	Shorter warranties & lifespan

Adapted from https://www.greenmatch.co.uk/blog/2015/09/types-of-solar-panels

The key components of a photovoltaic power system are:

- solar cells interconnected to form a photovoltaic module (the commercial product),
- mounting structure for the modules or array (several modules mounted and interconnected together to produce a desired voltage and current (power capacity)),
- inverter (essential for grid-connected systems and required for many off-grid systems),
- storage battery and
- charge controller (for off-grid systems only).

Performance of PV modules depends on the amount of solar irradiation received on the module surface, which varies with location and season. For this reason, systems normally need to be carefully designed for specific sites. Furthermore detailed information is available at Powering Agriculture Sustainable Energy for Food https://poweringag.org/docs/mooc-reader.

Figure 6 below provides an indication of the locations spread across the globe wherein solar energy could be integrated into energy systems given the intensity of solar energy hours/day at each location.

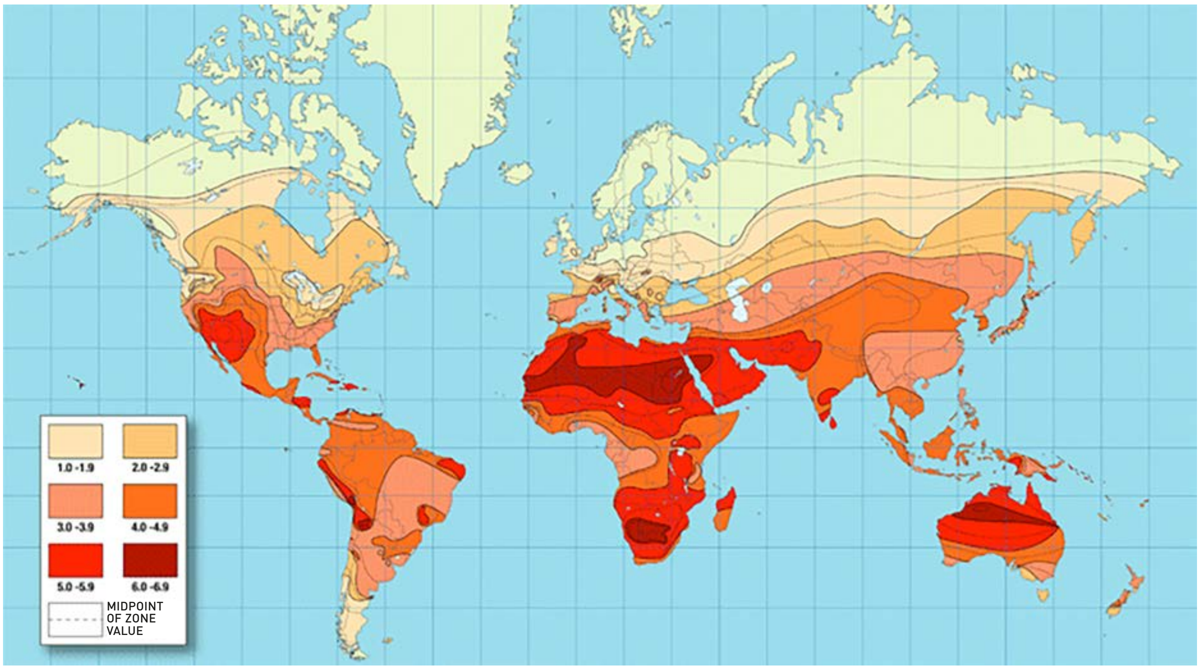


Figure 6 - Solar Isolation Map

This map is showing the amount of solar energy hours received each day on an optimally tilted surface during the worst month of the year. Source AltE Store available at https://www.altestore.com/howto/solar-insolation-map-world-a43/

Videos, webinars, articles and tools for solar and wind sourced energy
https://www.altestore.com/learn/

Advantages and disadvantages

Advantages:

- Solar power is pollution free and therefore does not increase GHGs after installation.
- Reduces dependence on oil imports and fossil fuels.
- Provides renewable clean power that is available at all times.
- Return on investment (ROI) is generally positive.
- Once installed Solar panels require very little maintenance.
- Excess power can be stored in batteries or sold.
- Can be used off grid because solar panels can be installed virtually anywhere.

Disadvantages:

- High initial costs for material and installation and long ROI.
- Needs lots of space as efficiency is not 100% yet.
- No solar power at night so there is a need for a large battery bank.
- Devices that run on DC power directly are more expensive.
- Depending on geographical location the size of the solar panels varies for the same power generation.
- Cloudy days do not produce much energy.
- Lower production in the winter months (further information available at https://www.sepco-solarlighting.com/blog/bid/115086/Solar-Power-Advantages-and-Disadvantages).

Example: Water pumping using solar technology

Droughts and irregular rainfall patterns have increased globally, contributing to the loss of at least 12 million hectares of arable land every year (UNCCD, 2011). Irrigation is among the measures that can reduce vulnerability to erratic rainfall patterns, substantially improve yields, and also potentially double and triple the quantity of crops grown per year (FAO, 2011).

Water pumping for crop irrigation and livestock watering requires energy. In areas that lack access to electricity, water pumping systems powered by diesel or petrol engines are used, but they are costly due to fuel transportation and maintenance needs. This is why affordable, renewables-based water pumps, such as solar pumps (Figure 7), are gaining popularity in remote areas.

The adoption of solar pumps has been driven mainly by the drastic drop in the cost of solar PV around 80% between 2012 and 2015 (IRENA, 2016a). System costs can vary significantly depending on the scale and location of the project and on whether after-sales services are included or not. Another factor driving the wide adoption of solar PV pumps is the continuing technological improvement of the pumping systems, enabling the market to provide suitable pumping solutions tailored to meet specific requirements and conditions, including the integration of PV pumps in hybrid systems.

At the farm level, economic benefits are realised through additional income from increased yields, the potential for cropping multiple times in a year and the production of high-value crops. In cases where diesel pumps are replaced with solar pumps, additional benefits include the reduced spending on fuel such as diesel. In addition, solar pumps have a lower environmental footprint compared to traditional options such as grid electricity and diesel-powered pumps.

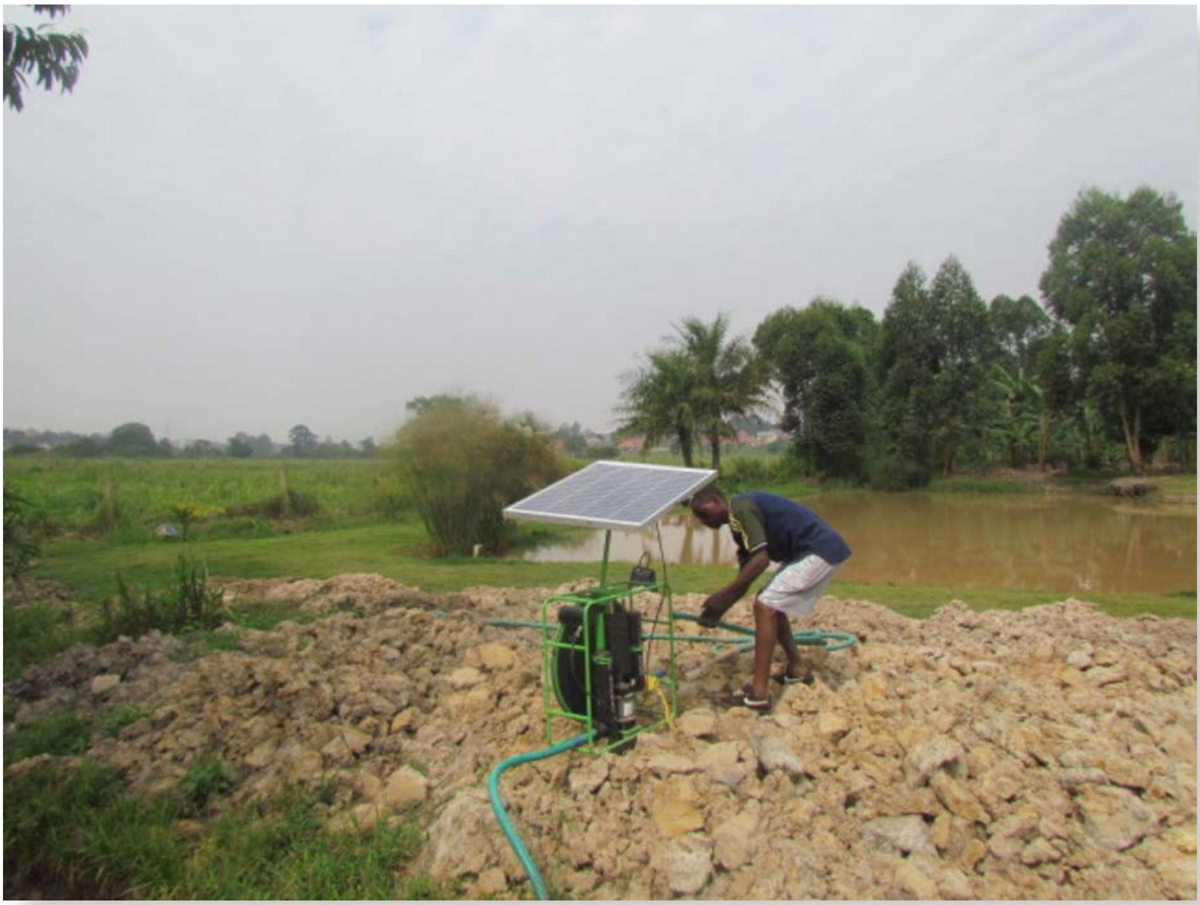


Figure 7 - Simple solar powered water pump - no source

Regardless of the technology used, renewables-based water pumping can enable clean irrigation which can increase income for farmers. However, special attention needs to be given to the risk of excessive water withdrawal. The rapidly decreasing costs of technology, the lower operation costs of renewables-based pumps compared to other energy sources (diesel or grid-based), and the growing number of countries announcing large-scale renewables-based pumping plans, taken together, increase the risk of over-withdrawal. The table below details the advantages and disadvantages of different RE based pumping technologies.

Table 3: Advantages and disadvantages of different RE based pumping technologies.

	Advantages	Disadvantages
Manual pumps	• Easy to maintain • Can be manufactured locally • Low capital cost • No fuel costs	• Loss of human productivity • Often an inefficient use of boreholes • Low flow rates
Wind pumps	• Unattended operation • Easy to maintain • Long life • Local manufacture is possible • No fuel costs	• Water storage required for periods of low wind speed • High system design and Project planning needs • Not easy to install
Solar PV pumps	• Easy to maintain • Easy to install • Unattended operation • Long life • No fuel costs	• High capital costs • Water storage required for cloudy days and after sunset • Repairs often required skilled technicians
Biogas pumps	• Use of dung benefitting waste management • Local manufacture is possible • No fuel costs • Can be dual with diesel	• Small amounts of dung required • Operation needs to be attended
Diesel and gasoline pumps	• Quick and easy to install • Low capital costs • Widely used • Can be portable	• Fuel supplies erratic and expensive • High maintenance costs • Short life • Noise and fume pollution

Source: Adapted from IRENA (2016).

3.1.3.5. Geothermal energy

Principles

Geothermal energy is defined as heat from within the earth that can be used for heating or to generate electricity. Geothermal literally means 'earth's heat' of which there are extreme amounts of heat found at the core of the earth. The temperature of the earth's core is estimated to be approximately 5000 °C, and the outer core is about 4000 °C (Figure 8). The constant flow of heat energy from the earth's interior which is equivalent to an estimated 42 million megawatts (MW) of power, is expected to continue for billions of years (Íslandsbanki, 2011).

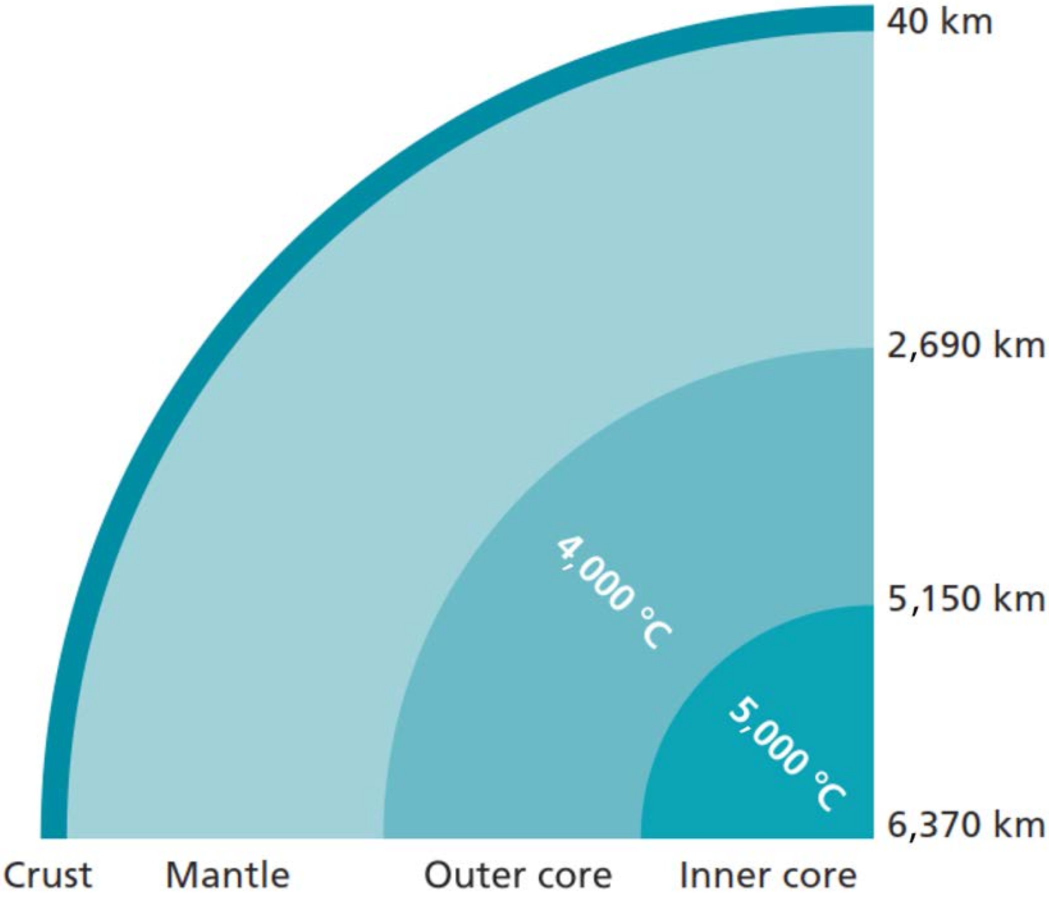


Figure 8 - Temperatures of the earth's crust, mantle, outer core and inner core layers (Source: P.G. Pálsson, 2013.)

Some of the resources of geothermal energy are hot rock found a few miles beneath the Earth's surface, and down even deeper to the extremely high temperatures of molten rock called magma. However, magma does not always come to the surface of the earth. If it stays trapped within the layers of the earth, it can heat underground water. This hot water is another geothermal energy resource. If the heated water within the earth does not reach the earth's surface, it remains as underground concentrations of hot water and steam, known as **geothermal reservoirs** (Figure 9). By tapping into geothermal reservoirs, we can efficiently heat our homes and businesses and even generate electricity.

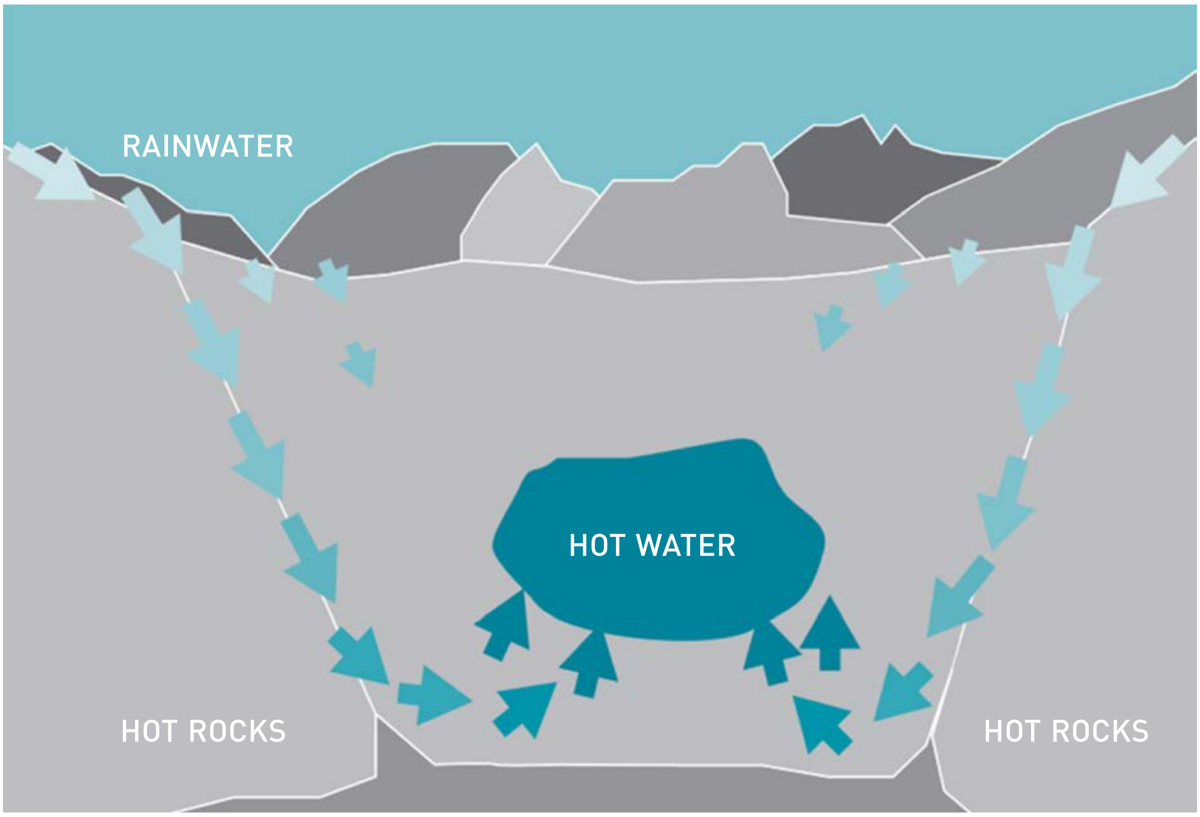


Figure 9 - Formation of a geothermal reservoir (Source: P.G. Pálsson, 2013)

Advantages and disadvantages

Advantages:

- There are a few polluting aspects to harnessing geothermal energy, and the carbon footprint of a geothermal power plant is seen as minimal. An average geothermal power plant releases the equivalent of 122 kg CO_2 for every megawatt-hour (MWh) of electricity it generates – one-eighth of the CO_2 emissions associated with typical coal power plants for the same amount of energy produced.
- Geothermal reservoirs are naturally replenished. According to some scientists, the energy in our geothermal reservoirs will last billions of years. While fossil fuels have an expiry date, renewable sources like geothermal energy is not going to expire anytime soon.
- The power output of a geothermal plant can be accurately predicted and is not subject to the same low-energy fluctuations as with solar or wind.

Disadvantages:

- Greenhouse gas below Earth's surface can potentially migrate to the surface and into the atmosphere. Such emissions tend to be higher near geothermal power plants, which are associated with sulphur dioxide and silica emissions. Also, the reservoirs can contain traces of toxic heavy metals including mercury, arsenic and boron.
- Construction of geothermal power plants can affect the stability of land. In January 1997, the construction of a geothermal power plant in Switzerland triggered an earthquake with a magnitude of 3.4 on the Richter scale.
- While there is a predictable ROI, it will does not happen quickly.
- Abundant geothermal reservoirs are hard to come by. Iceland and Philippines meet nearly one-third of their electricity demand with geothermal energy.
- Some studies show that reservoirs can be depleted if the water is removed faster than replaced.

More detailed information is available at Planetsave http://planetsave.com/2016/02/11/geothermal-energy-advantages-and-disadvantages/

Examples

- **Geothermal heat pumps**

Also known as ground source heat pumps, are systems that use the stable temperature of the earth to heat and cool buildings. A few feet below the surface of the earth, the temperature stays at about 10 degrees Celsius year-round. Geothermal heat pumps rely on this relatively constant temperature to both heat and cool buildings.

Water and other fluids are circulated through a loop of buried pipes as detailed in Figure 10. In the winter, heat from the ground is pulled into the building and circulated through a duct system. In the summer, the process is reversed. The building's heat is picked up by the circulating fluids within the pipes and transferred into the earth, helping to cool the building.

Geothermal heat pumps can also be used to generate electricity.

Geothermal System

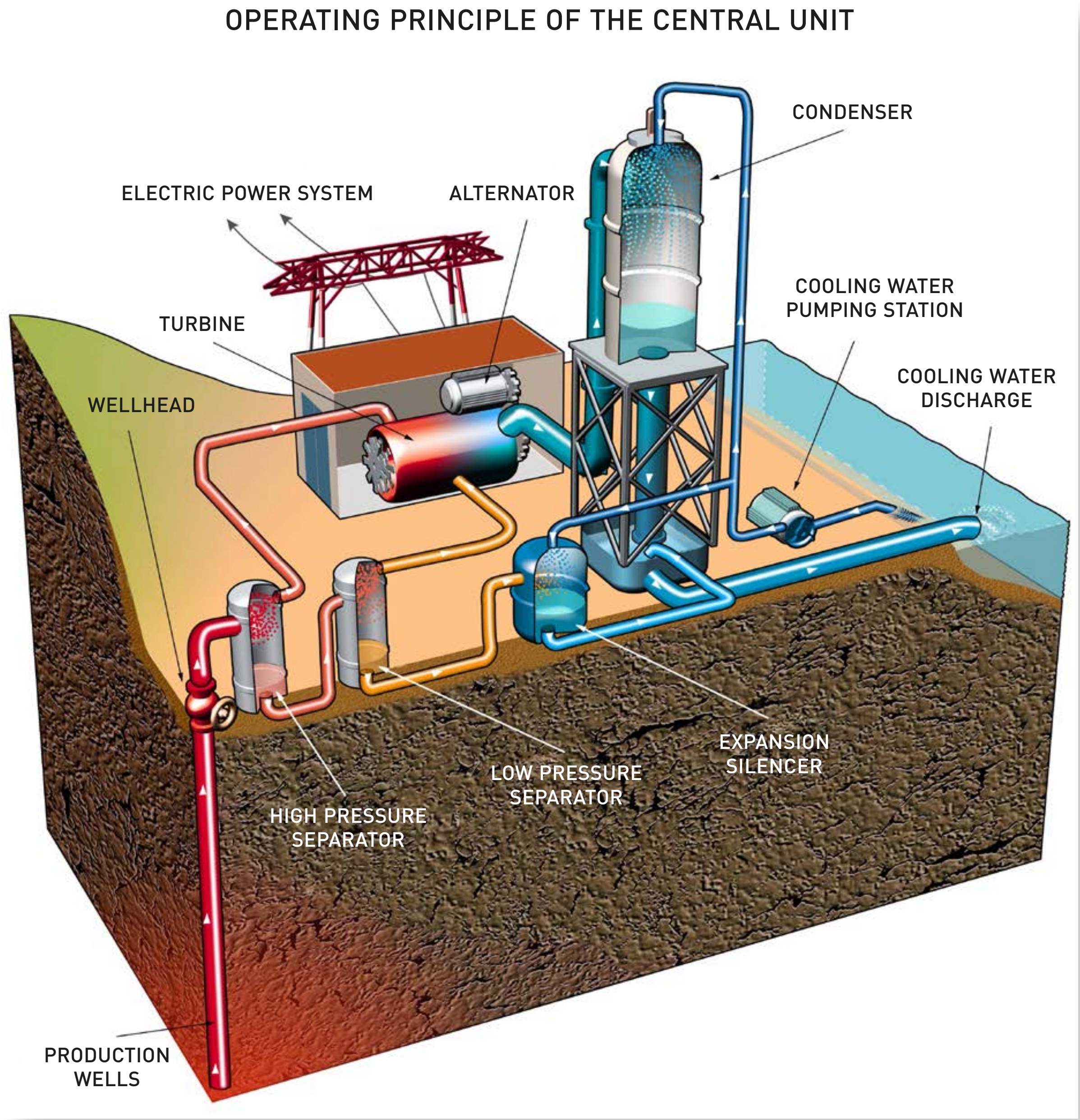


Figure 10 - Basic principles of a Geothermal System
(source http://www.ashevillegeothermal.com/Geothermal.php)

- **Geothermal power plants**

They are facilities that convert the Earth's natural heat into electricity. These plants drill wells into geothermal reservoirs to bring hot water and steam from deep within to the Earth's surface. All geothermal power plants use steam to spin turbines attached to electricity generators. However, there are three different types of geothermal power plants. Selection for a particular locality will depend on the temperature and pressure of the available geothermal reservoir.

1. A **dry steam plant** directly uses steam to spin a turbine. These systems use very little water, hence the name 'dry'. This is the oldest and least complex of the three designs, but because this is an open system, it can release hazardous substances, such as hydrogen sulphide, into the atmosphere.

2. A **flash steam plant** moves high-pressure geothermal water into low-pressure tanks to produce a flash of steam to spin a turbine. After the steam is used, it is cooled and condensed back into water and injected back down to the reservoir.
3. A **binary cycle plant** uses geothermal water to heat a secondary fluid that spins a turbine. The advantage of a binary cycle plant is that lower temperature geothermal water can be used to generate electricity. With this system, moderately hot water is passed through a heat exchanger, where it heats a secondary liquid that has a lower boiling point than water. This fluid then flashes to vapor to spin the turbine.

More detailed information is available at Study.com https://study.com/academy/lesson/geothermal-and-tidal-energy-advantages-and-disadvantages.html.

3.1.3.6. Tidal energy

Principles

Tidal energy is a renewable energy source. This energy source is a result of the gravitational fields from both the sun and the moon, combined with the earth's rotation around its axis, resulting in high and low tides. Tide or wave refers to the periodic rise and fall of water level of the sea. Tides occur due to the attraction of sea water by the moon. When the water is above the mean sea level, it is called flood tide. When the water level is below the mean level it is called ebb tide.

Tides contain large amount of potential energy which can be used for power generation. It is this difference in potential energy that is the source of power generation from tidal energy, whether we are talking about stream generators, tidal barrages or more the more recent technology, dynamic tidal power (DTP).

During high tide period, water flows from the sea into the tidal basin through the water turbine. The height of tide is above that of tidal basin. Hence the turbine unit operates and generates power, as it is directly coupled to a generator.

During low tide period, water flows from tidal basin to sea, as the water level in the basin is more than that of the tide in the sea. During this period also, the flowing water rotates the turbine and generator power.

The arrangement of this system is shown in Figure 11 the ocean tides rise and fall and water can be stored during the rise period and it can be discharged during fall. A dam is constructed separating the tidal basin from the sea and a difference in water level is obtained between the basin and sea.

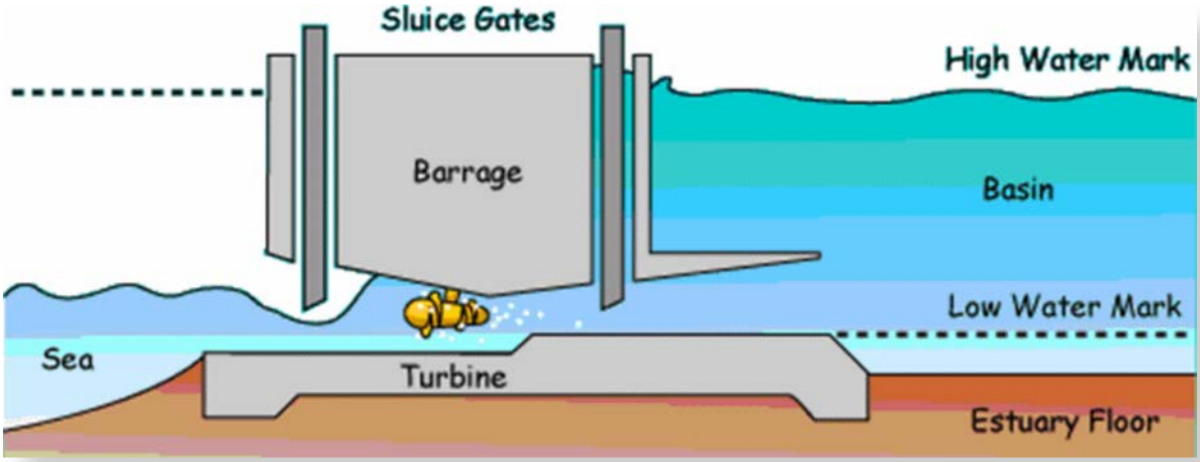


Figure 11. Principles behind tidal power plant
Source: https://re.emsd.gov.hk/english/other/marine/images/marine_tech_018.gif

The generation of power stops only when the sea level and the tidal basin level are equal. For the generation of power economically using this source of energy requires some minimum tide height and a suitable site. Kislaya power plant of 250 MW capacity in Russia, Rance power plant in France and one in Pentland Firth between mainland Scotland and Orkney with a calculated capacity of approximately 1.9 GW are some examples of this type of power plant.

Advantages and disadvantages

Advantages:

- Compared to fossil fuels or nuclear reserves, the gravitational fields from the sun and the moon, as well as the earth's rotation around its axis won't cease to exist any time soon.
- Tidal power is an environmentally friendly energy source. In addition, it does not emit any climate gases and does not take up a lot of space.
- However, there are currently very few examples from real tidal power plants and their effects on the environment. An important task is therefore to study and assess these things.
- Tidal currents are highly predictable. High and low tide develop with well-known cycles, making it easier to construct the system with right dimensions, since we already know what kind of powers the equipment will be exposed to.
- Because of this, even though the turbines that are being used (tidal stream generators that is) are very similar to wind turbines, both the physical size and the installed capacity has entirely other limitations.
- Water has 1000 times higher density than air, which makes it possible to generate electricity at low speeds. Calculations show that power can be generated even at 1m/s (equivalent to a little over 3ft/s).

Disadvantages:

- The effects tidal power plants have on the environment are not completely determined yet.
- Tidal barrages rely on manipulation on ocean levels and therefore potentially have the environmental effects on the environment similar to those of hydroelectric dams. Technological solutions that will resolve some of these issues are currently being developed.
- Tidal power plants need to be constructed close to land. This is also an area where technological solutions are being worked on.
- It is important to realize that the methods for generating electricity from tidal energy are relatively new technologies. It is projected that tidal power will be commercially profitable within 2020 with better technology and larger scales. More detailed information can be found at Energy informative available at http://energyinformative.org/tidal-energy-pros-and-cons.

3.2. EVALUATION TOOLS TO ASSIST WITH DECISION MAKING

It is important that a farmer chooses the most appropriate technology that is right for both the farm and enterprise energy needs. Farmers can choose renewable energy systems for very different reasons and property size and location may affect the types of renewable energy system that the farmer can choose.

The first thing a farmer has to consider is whether a renewable energy system will provide the required output. The next thing to consider is how the already existing farm operations can best be integrated with available renewable technology solutions. Consequently, many factors need to be considered:

- The amount of energy required by - and location of the enterprise
- How much the farmer is willing to spend?
- The size of any available grants/finance tools

All of these factors will have a role to play in the decision-making process for the various sizes of enterprises along the agro-food chain.

- Subsistence level: This is the smallest system in which households are engaged in basic forms of small-scale agricultural activities. They produce solely for their own consumption. Subsistence farmers use very low energy inputs, usually derived from human and animal power. These energy inputs are difficult to measure and not included in world energy statistics (FAO, 2011). For subsistence farmers priorities are gaining access to energy and securing an adequate livelihood. Lack of financial resources limits their ability to meet these priorities and to invest in sustainable energy solutions. Nevertheless, coordinated networks of subsistence farmers can benefit from renewable energy systems such as small-scale hydro, wind and solar powered systems.
- Small family units: They are usually engaged in a variety of activities, including cultivating small gardens or rice fields, tending orchards, raising livestock and maintaining dairy herds (FAO, 2011). In most countries small-scale farmers

provide fresh food to local markets and/or to processing plants. Depending on the degree of modernization, different renewable energy technologies and energy-efficiency options exist for these small enterprises. For instance small farms may utilize solar heat for crop drying, on-farm produced biogas for cooking and electricity generated from a solar photovoltaic (PV) system (FAO, 2011).

- Small businesses: The differences between small business and family units are that small businesses can be family-managed but are usually privately-owned. They usually operate at a slightly larger scale and employ several staff. Since these businesses have more capital available, they have opportunities to reduce their fossil fuel dependence by investing in on-farm renewable energy, which could also provide additional benefits to the surrounding local community.
- Medium sized businesses: Typically emerge from the slow and steady growth that results from a successful small business. As an enterprise earns more revenue, it sets aside the capital needed for buildings, equipment and more employees, eventually bridging the gap between small business and large corporations. Medium sized businesses tend to display continual growth trends.

The first step in the decision-making process is to conduct a feasibility study also known as a feasibility analysis.

3.2.1. Feasibility analysis

When planning an investment, the operator or project manager should first perform a feasibility analysis. This tool helps to determine whether or not a project can be completed successfully, taking legal, economic, technology, scheduling and other factors into account. It permits the analysis of possible positive and negative outcomes of a project before too much time and money are invested.

The first step involves the contextualization of the investment into an economic, institutional, social and technical framework. Constraints and challenges to the use of sustainable energy in agricultural and food industries in countries with low GDPs can indeed stem from these areas. A preliminary test for the value of the investment requires clear **identification of financial, economic, institutional, social and technical opportunities and risks.**

Some of these barriers would be considered in detail in the economic analysis, but first an identification of constraints is necessary. In fact the identification of significant barriers or constraints could make an investment in a specific technology unfeasible in a particular environment even though it might seem financially attractive in another environment.

In the case of investment in renewable technologies examples of constraint are:

- Lack of access to finance,
- High cost of capital,
- Market failures,
- Network failures,
- Insufficient legal and institutional framework,
- Lack of skilled person¬nel,
- Social, cultural and behavioural factors,
- Geographic constraints and sus¬tainability concerns.

3.2.2. Technical analysis

The adoption of the technology/practice from either behind or beyond the farm gate goes through different steps:

- Awareness by an enterprise/farmer who learns about the technology/ practice.
- Evaluation by an enterprise/farmer of the technology in terms of costs and benefits.
- Adoption by an enterprise/farmer who decides to adopt it in full but modifies or adapts it to suit the local situation and special needs.

The adoption of the technological option also depends on the risk perceived by the farmer/ enterprise therefore stakeholder involvement can also be relevant. Weak connectivity between actors, social biases and traditions may represent constraints to the adoption of sustainable energy technologies.

The methodology to perform a techno-economic analysis of the investment is the same regardless of the technology and value chain stage. The analysis performed in this lecture covers investments from production to processing but does not consider the commercialization stage.

Decisions regarding whether or not to invest in renewable energy technologies and energy efficiency, an agricultural and food enterprise would compare this option with the energy source or technology currently used (e.g. fossil fuels). Analysis from many demonstration and commercial renewable energy plants show that project costs are **very site-specific**. It is worth noting that **LCOE**, as it was explained in Chapter 1, of many renewable energy technologies are becoming more and more competitive with current average costs of fossil-fuel powered electricity (heat and transport and fuels) they displace. Moreover, costs for renewable energy technologies decline as the size of their markets increases.

In order to quantitatively assess the attractiveness of an investment, the economic/ financial tools, **CBA, LCCA or LCA**, depending on the size of the proposed investment/ project need to be applied to provide the indicators that will determine the long-term viability of the proposal. (**Refer to the appropriate Section of Chapter 1**).

The levelized cost of energy (LCOE) represents the cost of an energy gen¬erating system over its lifetime. Lev¬elized cost of electricity is often cited as a convenient summary measure of the overall competitiveness of differ¬ent generating technologies. It is cal¬culated as the per-unit price at which energy must be generated from a specific source over its lifetime to break even (recover all costs, includ¬ing financing and an assumed return on investment). LCOE usually includes all private costs that accrue upstream in the value chain but does not include the downstream cost of delivery to the final customer, the cost of integration, or external envi¬ronmental or other costs. Subsidies and tax credits are also not included.

‘With and without scenario’ - comparative analysis

Technical, financial and/or economic analysis of the investment requires a comparison with a benchmark that will provide a comparison between the potential situations 'with' or 'without' the project.

1. The first step is the identification and description of both the benchmark scenario (which normally consists of fossil fuel-powered and/or inefficient technologies) and the post-energy intervention scenario (where the technology is adopted).
2. For instance, an irrigation system can be powered by a diesel pump (benchmark scenario) or by a solar photovoltaic (PV) powered pump (post-energy intervention scenario). The financial analysis of an investment in the PV pump would require the comparison between the two scenarios.
3. The second step involves the identification of the investment outcomes, including capital and operating costs, and monetized benefits. Because costs and benefits do not occur at the same time – with costs generally preceding and exceeding benefits during the first years of the project – the comparison requires discounting techniques.
4. The third step is to determine the project’s incremental net flows (financial and/or economic), which results from comparing costs and benefits of the project with the benchmark scenario. It is possible to calculate the corresponding project profitability indicators with these elements.

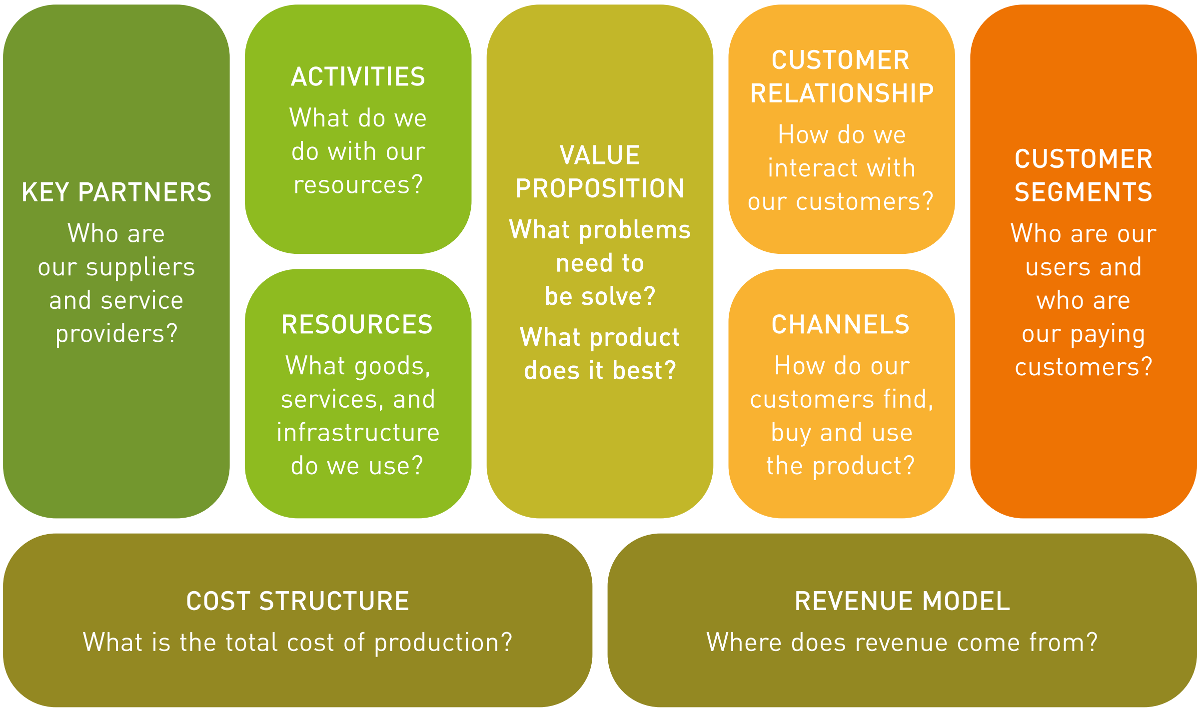
However, if the proposal/project is large enough the technical, economic/financial information needs to be considered in the context of social and environmental impacts.

The FAO Nexus Assessment (FAO, 2014) is a tool that can be used to introduce basic social and environmental externalities of a technical intervention into the analysis. This assessment consists of an easily applicable methodology to quickly evaluate possible interventions in a specific context against overarching development goals, such as food security, and the sustainability of energy and water supply, use and management. A simplified version of this tool, the Water-Energy-Food (WEF) Nexus Rapid Appraisal, can be used for a desk assessment of the impacts of an intervention on water, energy, food, labour and costs in the context of a specific country. (Walking the Nexus Talk: Assessing the Water-Energy-Food Nexus in the Context of the Sustainable Energy for All Initiative (PDF) (FAO, 2014).

3.2.3. Business models

Business models are not only developed for a completely new business, but also apply to changes within an existing business e.g. introducing energy efficiency measures in enterprises along the agro-food chain. Although a business model is a fundamental part of financial activity, the term is understood and defined in many different ways. To put it simply, **a business model describes the core strategy of an organization for how to generate money and by this determines how the company produces, distributes, prices and promotes its products**. A business model can also be defined as "the specific combination of the product made and sold by the firm, the technology utilized, and the scale of production, backward and forward market linkages and financing arrangements" (ValueLinks Association, 2009 available at http://valuelinks.org/).

All new businesses with an idea that needs to be translated into reality, this is where business modelling begins. Also, established businesses develop new business models for instance, optimizing a core process affects the business model. An example is improved energy access e.g. for a diary collection centre that is now able to cool the milk using clean energies and thereby increase added-value. Establishing a new business or a start-up into a long-term successful business requires a well-defined business model that will be developed following steps illustrated in the canvas presented in Figure 12.



KEY PARTNERS
Who are our suppliers and service providers?

ACTIVITIES
What do we do with our resources?

RESOURCES
What goods, services, and infrastructure do we use?

VALUE PROPOSITION
What problems need to be solve?
What product does it best?

CUSTOMER RELATIONSHIP
How do we interact with our customers?

CHANNELS
How do our customers find, buy and use the product?

CUSTOMER SEGMENTS
Who are our users and who are our paying customers?

COST STRUCTURE
What is the total cost of production?

REVENUE MODEL
Where does revenue come from?

Figure 12 - Generic canvas from which a business model or ecosystem*

***Business ecosystem** - A strategic planning model, popular since the development of information technology, whereby a network of suppliers, distributors, competitors and customers all work through competition and cooperation to advance sales of products.

To be able to answer the questions posed in the business model canvas, it is recommended that some form of market research and analysis be carried out. Talk to people who do similar business and ask them to share their experiences. Talk to potential clients and find out what they think about the business idea, and what additional services or product features they would value. Market analysis also includes identifying competitors and characteristics of potential customers, including their willingness to pay. In addition, production costs need to be identified as they will affect any profit margins can be attained by selling the product or service.

Another possibility is that you are already operating a business. Integrating a **clean energy solution** in your processes could be an option to increase the energy-efficiency and/or productivity of the business. Changing processes might impact a business model, as aspects like cost structure and key resources need to be adopted. For instance, if diesel generators of an irrigation system are replaced by a PV plant, then the cost of diesel is eliminated from the **indirect costs**. Instead the purchase and operating costs of the PV plant need to be factored into the **direct costs.** The installation of a PV irrigation system will enhance agricultural productivity. All these factors will of course affect the financial aspects of a business model, the terminology of which is explained in the table below.

Table 4: Definition of financial terms

Term	Definition
Direct cost	Costs that are directly related to the production of a particular service or good e.g. material, labour and other production expenses.
Indirect cost	Costs that arise but cannot be assigned to a particular produced good or service. They are necessary to keep the business operational. Examples are utilities, rent, plant maintenance, administrative costs, etc.
Opportunity cost	It is the 'cost' incurred by losing the benefits of a second-best alternative.
Capital cost	One-time expense to establish a plant or project.
Interest rate	The cost of borrowing money as it is calculated on an annual basis.
Profit	Total revenue – total costs.
Revenue	Income earned by a business through the sale of services or goods.
Cash flow	Incoming and outgoing cash of a business.
Discount rate	This rate is generally used to bring future cash flows to their market value at the present-time. It is an indicator for the 'risk' involved of a proposed investment.

Adapted from Powering Agriculture MOOC Sustainable energy for food available at https://poweringag.org/mooc

Tools that can be deployed to assist with the development of Business Models can be found at:

- *Boston Matrix:* to support your decisions on which products you could invest in analysing their market share.
- *PEST(LE)* (political, economic, social, technological, legal, and environmental): the framework helps to analyse external macro environmental factors that might influence your business. Results can be used for the SWOT Analysis.
- *SWOT Analysis* (strengths, weaknesses, opportunities, threats): for planning and marketing strategy. It helps you to analyse your internal business capabilities against the realities of the business environment, to lay the foundations for a successful business.

Available at https://www.jisc.ac.uk/guides/managing-strategic-activity/prioritisation

In most cases clean energy solutions for agricultural value chains require a significant investment. Hence, access to finance is crucial and often the biggest challenge for rural farmers, as well as for renewable energy project developers and service providers. Usually there are two ways for investors to source capital, either by borrowing it from a bank, or through equity capital (i.e. selling a stake in the business). The scale of investment will depend on the size of the proposed energy system, ranging from e.g. small biogas plants for smallholder farmers, via bigger PV-powered cold rooms for vegetables, up to wind parks for generating energy for flower farms. Different types of financing vehicles/tools will be required for an energy transition, the choice of which is related to the size of the proposal and the investment required.

3.2.4. Community involvement for off-grid rural electrification projects

Generally, electrification projects are established and operated either through public utilities or private ownership. However, the level of investment required to establish off-grid facilities owned and operated by either type of entity without some kind of donor organisation or community involvement is high and tariffs will be beyond the reach of many small landholders or sole operators.

In the low GDP countries, rural electrification projects, especially small scale non-grid electrification projects, are often sponsored by bilateral or multilateral donors, or international organisations. In that case, an international or local NGO can carry the responsibility of developing the power plant and the distribution network, and they will often hand over the responsibility of running the plants when they have been fully developed to a local public utility or a community cooperative.

3.2.4.1. Community cooperatives

Community based cooperatives, or co-owned power systems, are mainly used for mini-grid programs in isolated areas that do not attract private-sector or utility interest.

Here the cooperatives become the owners and operators of the system and provide maintenance, tariff collection, and management services.

A strong feature of the community cooperatives is that the owners are also the customers, and therefore have a strong interest in the service and quality of the output. Furthermore, they are tailor-made tariffs for the customers. The downsides of community cooperatives are that they often lack the technical skills to design and run the power systems and the business skills to often less bureaucratic than public utilities, can create jobs in the local community, and make implement a sustainable business plan. This model therefore requires substantial technical assistance. The local capacity for operation and maintenance needs to be assessed from the outset of a project, and a mechanism for allocating resources for operation and maintenance should be agreed on. This is also important in other types of ownership but is especially important for community cooperatives, as they take on a completely new task.

Another challenge with the community model is that there is a high risk of social conflicts within the community. Disputes of who has paid for what and who should benefit and at what price should be avoided through sociological, technical and economic approaches including the social shaping of the committees and the rules of leadership. In general, community owned rural electrification projects require a long preparation period and a great deal of technical and social capacity building to be successful.

3.2.4.2. Ownership and community involvement

Ownership and sustainability is dependent on community involvement through all phases of the project from project start up, through project implementation and until project handover. The three phases of the project in which community involvement is required in order to ensure the sustainability of any type of community off-grid RE project – are illustrated in the figure below.

Figure 13 - Three phases of Project
Source ACP-EU Energy Facility Thematic Fiche No. 8 Sustainability II: Ownership and Community Involvement.

3.2.4.3. Pros and cons of community involvement and ownership

Community involvement can have positive consequences for both the community and project implementer. The community will get a degree of control over the project, it might get a financial return from the project or other tangible benefits, and if successful the project will provide a sense of satisfaction. The project implementer will get valuable information for the project design. Moreover, community involvement can handle demand side issues, e.g. explaining what electricity can be used for. Community involvement can be a useful process to overcome critics and dissatisfaction during project implementation, and in some cases even to avoid thefts and vandalism against the project.

The challenge with community involvement is that it is often a very time-consuming process. Consequently, honest attempts of involvement bear the risk that the community might have other needs and hopes than the project implementers expected or planned, the consequence being that the project plans and objectives need to be revised during project implementation. Finally, the project implementer should be aware of the fact that involvement creates expectations and failing to reach these expectations might create disappointment and dissatisfaction amongst the beneficiaries.

Community involvement and acceptance can be cemented from the first stage of project design. In other words, if the community is involved in the project design from inception then the long-term sustainability of the project is more likely to be assured. The first four steps involved of any project start-up are outlined in the figure below.

Figure 14 - Four steps involved in Project Start-Up

More detailed information on RE Off-Grid Project Design, Implementation and Management is available at http://energyfacilitymonitoring.eu/ and https://ec.europa.eu/europeaid/regions/african-caribbean-and-pacific-acp-region/acp-multi-country-cooperation/energy_en.

The important thing to note and remember about any community involvement in any off-grid or RE integration project is that it involves 'community participation' in a total sense if it is to be sustainable over the long-term. Therefore, it is imperative that initiators of such community ventures are not only aware of the need for community participation through all stages of the project development and delivery, but that there are professionals involved who are skilled in participatory processes. In the Box below details such a community venture and the approach adopted to participation.

Malawi - 9 ACP RPR 49/29: Msamala Sustainable Energy Project

In this project Concern Universal uses the **REFLECT*** model for participatory development.

This development approach is used to empower the community. The project trains community

REFLECT facilitators in participatory approaches. They assist the community in developing a problem analysis and in identifying what actions should be taken. The identified solutions lead to the development of micro projects. Some of these projects can be carried out by the community without support. Other calls for external assistance. Concern Universal assists the community in implementing the micro projects such as development of participatory forest management plans and local tree planting to overcome a problem of deforestation.

Source: ACO-EU Energy, Facility Thematic Fiche No. 8 Sustainability II: Ownership and Community Involvement.

* Detailed information on reflective participatory development is available at:

- http://www.participatorymethods.org/method/reflective-practice
- Rural Invest - A Participatory Approach to Identifying and Preparing Small/Medium Scale Agricultural and Rural Investments: developed by the FAO Investment Centre, it provides support to local communities, private entrepreneurs or producers' associations to conceive and implement their own investment projects through a range of materials and training courses including technical manuals, custom-developed software, user guides and instructor materials available at http://www.fao.org/fileadmin/templates/tci/docs/RuralInvest/RuralInvest_Brochure_-_English__MF__-_9_dec15.pdf

Additional resources related to micro assessments of investment into RE can be found at:

Video:www.giz.de/gc21/pa_video_lectures

Material:
https://gc21.giz.de/ibt/var/app/wp385P/2624/index.php/additional-materials/

References: https://gc21.giz.de/ibt/var/app/wp385P/2624/index.php/references/

Sources of additional information for the financing of community projects:

AFD *"Green Credit Line"*: Providing commercial banks with an incentive to explore the renewable energy and energy efficiency markets. - https://www.afd.fr/fr

Energypedia *"Financing Portal"*: Information on funding and financing possibilities to bridge gaps in the financial renewable energy sector -
https://energypedia.info/wiki/Portal:Financing_and_Funding

GIZ *"Financing Green Growth"*: A review of green financial sector policies in emerging and developing economies (covering both small- and large-scale renewable energy and energy efficiency investments) -
http://www.greengrowthknowledge.org/resource/financing-green-growth-review-green-financial-sector-policies-emerging-and-developing

PAEGC *"An Energy Grand Challenge for Development"*: Supports new and sustainable approaches to accelerate the development and deployment of clean energy solutions in developing countries -
https://poweringag.org/about

UNEP *"Financing Renewable Energy in Developing Countries"*:
Drivers and barriers for private finance in sub-Saharan Africa -
http://www.unepfi.org/fileadmin/documents/Financing_Renewable_Energy_in_subSaharan_Africa.pdf

UNEP *"Private Financing of Renewable Energy – A Guide for Policymakers"*:
How finance generally works / the role of different parts of the finance sector / what issues financiers consider when investing, including the role of policy and regulation / others -
http://fs-unep-centre.org/sites/default/files/media/financeguide20final.pdf

World Bank *"Readiness for Investment in Sustainable Energy"*: Compares the investment climate of countries across energy access, energy efficiency and renewable energy- http://rise.worldbank.org/

Additional resources related to micro assessments of investment into RE can be found at:

Video www.giz.de/gc21/pa_video_lectures

Material gc21.giz.de/ibt/var/app/wp385P/2624/index.php/additional-materials/

References gc21.giz.de/ibt/var/app/wp385P/2624/index.php/references/

3.3. DECENTRALISED RENEWABLES FOR POST-HARVEST STORAGE, PROCESSING, TRANSPORT AND DISTRIBUTION

Almost one-third of the food produced for human consumption, roughly 1.3 billion tonnes, is lost or wasted each year, with a value of USD 1 trillion (FAO, 2012). The lack of proper post-harvest storage, processing and transportation facilities is estimated to cause global losses as high as 45% for fruits and vegetables and roots and tubers, 35% for seafood and fish, 30% for cereals, and 20% for dairy, meat, and oilseeds and pulses.

3.3.1. Dryers and stoves

Off-grid renewable energy technologies can be used to dry fruit, grains, rice, fish, corn and other agricultural products. Drying food saves for future use a considerable portion of the harvest that otherwise might be lost to mould. The use of a renewables-based dryer is more efficient than the traditional drying method of simply placing the fruit on a shelf under the sun, as the chamber of the dryer protects the fruit from insects, dust and primarily rain, which could damage a large part of the production, especially in tropical areas where rain and humidity are common. In addition, a renewable- based dryer makes it possible to dry larger quantities of products in a shorter period of time (Powering Agriculture MOOC https://poweringag.org/mooc). The most commonly used technology for drying produce is derived from solar energy, but other technologies derived from geothermal and biomass sources have been considered.

3.3.1.1. Solar dryers and stoves

Solar dryers piloted by Fullwell Transform, Makerere University and Fruits of the Nile in Uganda start to be replicated across the country (November 2017).

Cyrus Galyaki, a former Fullwell Transform hire, is promoting and installing solar dryers across Uganda, based on a design piloted by Fullwell Transform, Makerere University and Fruits of the Nile. Cyrus is a graduate of Agricultural Engineering at Makerere University, where he worked under the University in collaboration with Fullwell Transform, to design and build an improved solar dryer for research and demonstration purposes.

The success of the demonstration solar dryer led Fullwell Transform to develop a small project to pilot the installation of 3-4 of the solar dryers in Fruits of the Nile's banana and pineapple supply chains. Fullwell Transform secured the necessary funding and hired Cyrus to help install the dryers.

These installations are now complete, and Cyrus has since started his own business that focuses on the installation and repair of equipment for agricultural processing SMEs. His offering includes solar dryers and greenhouses based on the design piloted by Fullwell Transform, Makerere University and Fruits of the Nile, and to date he has completed nine installations with more in the pipeline. The design of the dryers is easily modified, including increasing the scale of the dryers, but the basic design remains mostly the same.

Some of the dryers are being used for research and development purposes, which are already helping to catalyse the scaling of adoption. Products that are either being dried or are being planned to be tested in the driers include moringa leaves, pineapple, jackfruit, pumpkin, banana, cocoa and cassava. These are intended for export as well as local markets. The locations of the driers are spread across Eastern, Western, Central and Northern Uganda.

Figure 15 - Solar Dryer example 2

Compared to traditional solar dryers, the improved solar dryers (Figure 15) allow drying to take place even on cloudy days, which in addition allows producers and dryers to increase output also to reduce spoiled product and resulting loss. The temperature inside the improved dryers is good, even on cloudy days, and remains so up until around 9.30 pm., long after the sun has set. The solar dryers have a Return on Investment (RoI) of only around 6 months (more information available at Fullwell Transform http://www.fullwelltransform.org/).

Solar-powered stove

These stoves are often considered "a solution looking for a problem". Solar cookers have long been presented as an interesting solution to the world's problem of dwindling fuel wood sources and other environmental problems associated with wood fuel demand for cooking.

Figure 16 - Solar-powered stove

A variety of factors influence solar cooker use rates, which in turn determine impacts. Some factors are related to the user, some to the environment in which the cooker is used and some to the cooker itself. These solar stoves can for instance by small scale processors to preserve fruits by making jams and jellies. Fresh fruits are boiled on the example stove in Figure 16 with a solution of cane or sugar until sufficient water has been evaporated to give a mixture which will set to a gel on cooling.

3.3.1.2. Drying produce using biomass and geothermal RE technologies

Cashew nut processing

Only a few years ago, Gebana Afrique's cashew processing factory based in Bobo-Dioulasso, Burkina Faso used large quantities of firewood and butane gas for generating the thermal energy needs for its steaming and drying processes, representing a significant cost to the business (see Figure 17 below). Both of these sources of energy produce relatively high levels of GHGs, affect workers' health, are costly to source and maintain and finally have a cumulative negative impact on the environment.

The use of wood as a source of fuel, whether it be for domestic or industrial use, is contributing to local and global deforestation. The drying process releases pollutants during combustion that have negative consequences for both people's health in the immediate vicinity as well as for the greater environment.

Figure 17 - Wood and butane gas used for steaming and drying cashew nuts.

At the same time, cashew processing generates a waste stream that represents around 75% of the weight of the Raw Cashew Nuts (RCN) that enter factories for processing into finished cashew kernels. Organic waste streams like these can additionally have negative impacts on the greater environment. Specifically, in the case of cashew, their shells contain a phenolic liquid called Cashew Nut Shell Liquid (CNSL), and if these shells are left to decompose they will cause damage to, including a blackening of, the earth. The toxins from these shells can also represent a problem for water systems, such as when heavy rains can wash large volumes of shell waste into rivers, which people also rely on for various domestic purposes in contexts like Burkina Faso. Additionally, cashew shells possess significant calorific value, and hence represent a potential fire risk.

Thus, this waste stream represented a problem for Gebana Afrique, as it cost the business money to dispose of but most of all, it posed problems and risks for the neighbourhood in which the factory is situated.

Nowadays, the factory does no longer uses any firewood, or butane gas, and is able to generate all of its thermal energy needs, from its own waste stream. This has improved the financial viability of the factory, and also helped enable a scaling of the factory's capacity.

Figure 18 - Gasification/pyrolysis

This has all been made possible as a result of the innovation of appropriate waste-to-energy and linked tunnel drying technologies by Fullwell Transform and French NGO, RONGEAD illustrated here in Figure 18 above. A process known as gasification/ pyrolysis is used to generate a combustible gas from cashew nut shell waste. The gas is then ignited and used to produce steam for all the steaming and drying processes within the factory. Furthermore, at the end of the gasification/ pyrolysis process, the cashew nuts shells are turned into charcoal, which Gebana Afrique has decided to distribute to its workers for free as illustrated in Figure 19 below. This reduces the amount of firewood charcoal or firewood used by these workers in their homes, saving them a little money and also reducing the amount of firewood used generally.

Figure 19 - Charcoal by-product

The gasifier/pyrolyser and linked drying system at Gebana Afrique has a Return on Investment (ROI) of only 2–3 years. Having realised the economic benefit of the technologies, Gebana Afrique has invested in a second system, to help it smooth operations and increase its potential capacity further. Fullwell Transform has also innovated scaled-down versions of the gasifier/ pyrolyser and linked drying system in use at Gebana Afrique, so they can be used by smaller cashew processors, and has so far installed two of these with women's groups in and around Bobo-Dioulasso. Whilst a reduction in scale tends to increase ROI, in this case the ROI remains at around 2–3 years as with the larger system at Gebana Afrique, given the technologies have been able to be scaled down.

Gasifiers/pyrolysers can work with a range of biomass, and hence be used in the processing of a wide variety of agricultural products. They can also be used without tunnel dryers where there is no drying requirement, such as when only a steaming operation is required.

The gasifiers/pyrolysers actually only require around 25% of the cashew nut shell waste volume from the processing operation to generate all the energy required for the factory's thermal energy needs. So Gebana Afrique is still left with a significant waste stream (75%). Thus Fullwell Transform has also innovated a carboniser/ charcoal kiln in partnership with the University of Zaragoza and Foundation 2ie that can produce a high-quality charcoal from cashew nut shell waste, and additionally produces CNSL as a by-product refer Figure 20 below.

This cashew nut shell charcoal (CNSC) has been tested by a laboratory as well as in 'the field' and been found to require a lower quantity for a given heating requirement as compared to firewood charcoal, to the tune of one quarter to one third less. The impact of this is that it has the potential to be sold at a higher price than firewood charcoal, or at the very least be a more interesting product than firewood charcoal if sold at the same price, due to its additional value. Additionally, whilst there is a lot more development to do on the CNSL side, which Fullwell Transform is seeking R&D funding for, tests have been done in Burkina Faso on its suitability as a bio-fuel, with some promising initial results.

Figure 20 - High quality charcoal produced from a carboniser/ charcoal kiln

These extra innovations have the potential to allow cashew processors like Gebana Afrique to convert their waste streams to value, and form a part of their business model, something that is desperately needed within the African cashew processing industry right now. Additionally, since both CNSC and CNSL are derived from agricultural residues, and are therefore renewable, they have the potential to displace other, unsustainable and environmentally damaging fuels, such as firewood, wood charcoal and oils (Source RONGEAD and Fullwell Transform available at http://www.fullwelltransform.org/what-we-do/innovate-catalyse-adoption-of-appropriate-technologies-and-solutions-at-scale/gasifiers-pyrolysers/).

Steam-powered tunnel dryer fuelled with fossil-based energy and renewable energy

In Burkina Faso a steam-powered tunnel dryer linked with a gasifier are used to produce dried mango. By linking this gasifier some of the energy required to fuel the steam dryer is generated using mango waste as well as other bioenergy sources. Some of the benefits of this approach to an innovative use of bioenergy sources are as follows:

- Improved quality, hygiene and uniformity of drying but also a better yield and value of dried product (1st grade).
- Suitable for a wide range of products and it also has potential for new premium quality ranges.
- Controlled and reproducible drying characteristics with drying temperature control.
- Reduced operating costs compared to the traditional butane/ LPG dryer: up to eight 12.5 kg bottles of gas saved per cycle for a tunnel type dryer in the case of producing dried mango.
- Local know-how has been deployed for the design, materials, manufacturing,
- installation and local maintenance.
- Modelled for different scales of operation ("Tunnel" and "small SME" (Table 5)) and
- modular with the possibility of several dryers operating in parallel.
- Affordable and renewable sources of biomass energy – potential for reducing SME waste streams (e.g. mango waste in the case of producing dried mango) as well as other sources of renewable biomass, in an eco-responsible manner.

Table 5: Tunnel and Small SME dryer - Systems Cost[6] and Return on Investment[7]

Parameters	Tunnel type dryer			Small SME dryer		
Dryer capacity (fresh product weight)	1,000 kg			320 kg		
Number of dryers (drying chambers)	1 1,000 kg	2 2,000 kg	3 3,000 kg	1 320 kg	2 640 kg	3 960 kg
Total production (fresh product weight)	1	36,000 £	48,000 £	14,500 £	20,800 £	27,200 £
1,000 kg	2			6,350 £		
2,000 kg	3	290	435	46	93	139
3,000 kg	1	1,314	1,971	292	584	876
320 kg	2	0.9	0.8	2.2	1.6	1.4
640 kg	3	0.4	0.3	0.8	0.6	0.6
960 kg						
Full system cost – H_2CP Gasifier/ Pyrolyser, boiler, dryers	£25,000	£36,000	£48,000	£14,500	£20,800	£27,200
Dryer unit only	£11,500	£6,350				
Butane savings (kg/day)	145	290	435	46	93	139
Reduced CO_2 emissions for season of 100 days (tCO_2eq/year)	657	1,314	1,971	292	584	876
Return on Investment on full system for season lasting 100 days (years)	1.3	0.9	0.8	2.2	1.6	1.4
Return on Investment on full system for continuous production over the year (years)	0.5	0.4	0.3	0.8	0.6	0.6

Source www.fullwelltransform.org

Biomass can be used for drying products such as bamboo. Bamboo is a valuable commodity that is used in construction and furniture, but it requires drying to make it suitable for domestic and international markets. African Bamboo, an Ethiopian company, uses a biomass-powered thermal process that combusts the biomass to dry bamboo, as the use of gas provides more heat control than wood. This can benefit more than 2,200 Ethiopian farmers from 30 co-operatives.

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[6] Do not include any extra building work required such as concrete platforms and roofing.

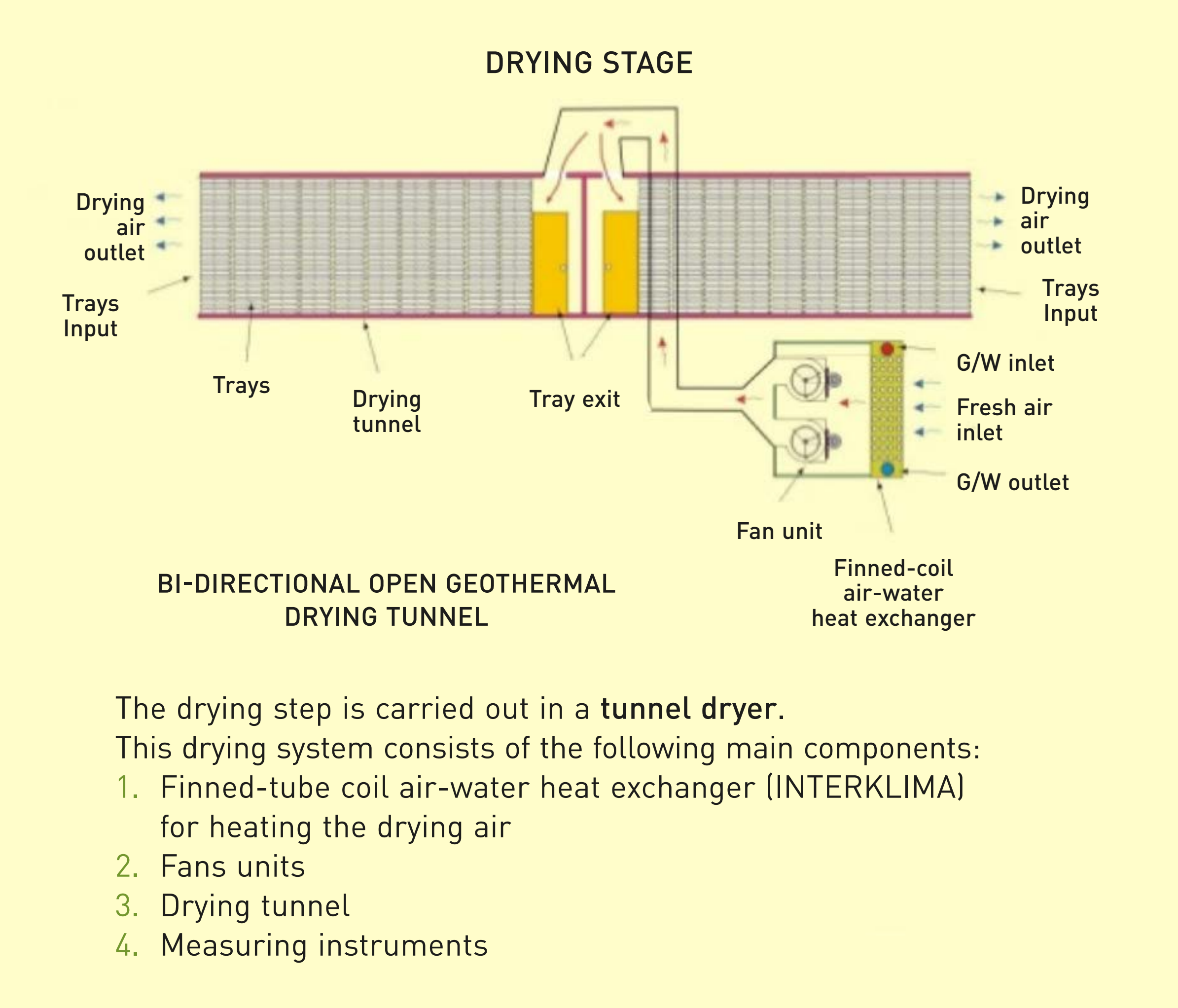
[7] ROI is calculated on the basis of fuel savings as well as processing benefits (e.g. less waste, more higher grade product).

Figure 21 - Biomass-powered dryer

Geothermal – When feasible, geothermal dryers can be used to dry grain crops and beans. In this example it is used for drying tomatoes. The direct use of geothermal heat has been developed in Indonesia for drying cocoa, copra, mushroom and tea (FAO *et al.*, 2015). However, the deployment of this technology faces constraints, including technical and financial barriers, and depends largely on government intervention.

In addition to food drying, refrigeration is a vital method for the preservation of perishable food.

DEHYDRATION OF TOMATOES



The drying step is carried out in a **tunnel dryer**.
This drying system consists of the following main components:

1. Finned-tube coil air-water heat exchanger (INTERKLIMA) for heating the drying air
2. Fans units
3. Drying tunnel
4. Measuring instruments

Figure 22 - Geothermal-powered dryer

3.3.2. Cooling system

There are a number of Off-grid renewable energy technologies available that can be used for cooling and cold storage of agri-food products. Farmers and processors of agri-food use cooling and cold storage to maintain food quality after harvesting and processing but also to reduce losses along the supply chain. Some of the technology used for cooling and cold storage of produce are presented in the following sections.

3.3.2.1. Evaporative cooling

In areas with no access to affordable modern technologies, low-cost alternatives such as evaporative cooling can be used to store and preserve food. Evaporative cooling is a basic principle that relies on cooling by evaporation. It is simple and does not require any external power supply. The system can be used for storing food for a longer time, protecting it from humidity and the development of fungi. Moreover, it prevents disease by keeping flies off the food and preserves the nutrient content of the vegetables as demonstrated in the figure below.

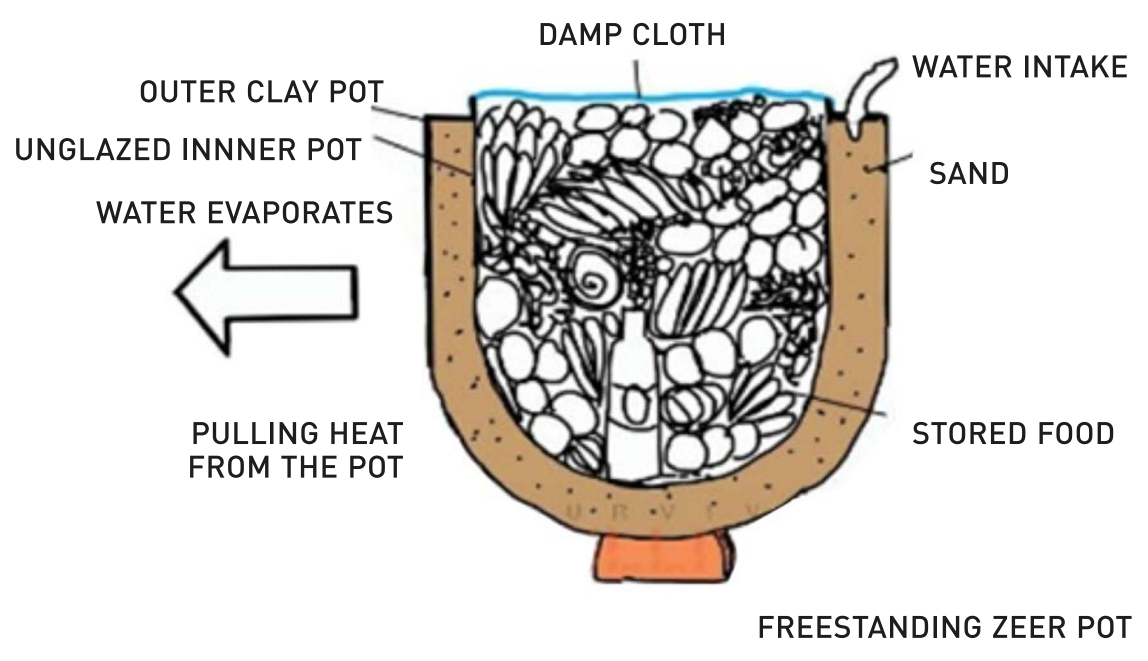


Figure 23 - Free standing Zeer Pot as used in Nigeria for Evaporative Cooling

Evaporative cooling occurs when air that is not too humid passes over a wet surface. When the water evaporates, it draws energy from its surroundings, which produces the desired cooling effect. The efficiency of an evaporative cooler therefore depends on the humidity of the surrounding air, as dry air can absorb a lot of moisture (providing greater cooling), whereas humid air that is totally saturated with water allows for minimal evaporation. An evaporative cooler generally consists of a porous material that is fed with water. There are various designs for evaporative coolers, depending on the materials available and the users' requirements.

'Zeer' pot cooling is among them. This 'pot-in-pot' system consists of two pots of slightly different sizes. The smaller pot is placed inside the larger pot, and the gap between the two pots is filled with sand, creating an insulating layer around the inner pot. The sand is kept damp by adding water at regular intervals.

3.3.2.2. Solar thermal and biogas cooling

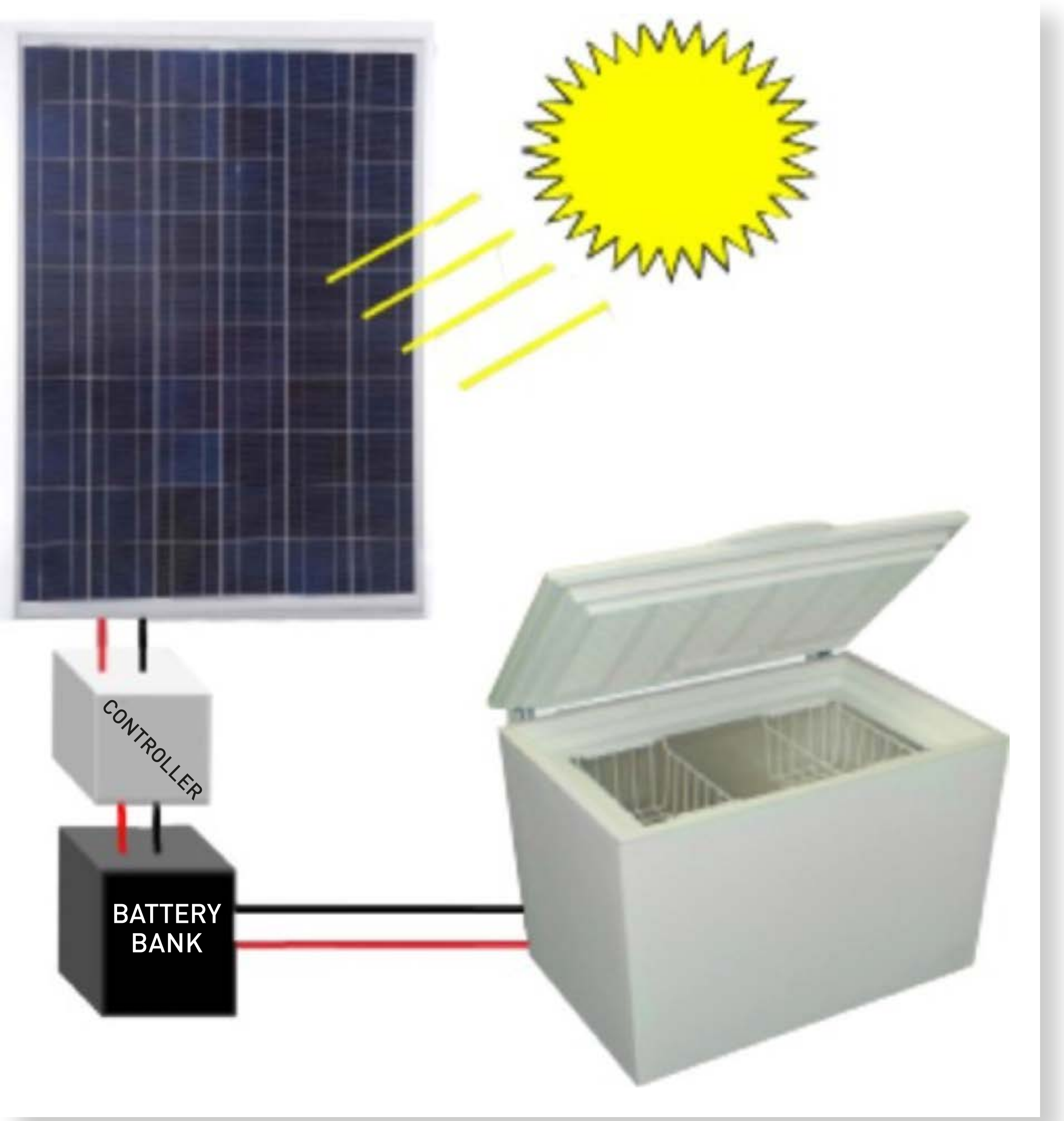


Figure 24 - Solar driven refrigeration – no source

Solar thermal refrigerators can be used for food preservation and for vaccine storage in areas that lack access to electricity and that have a high intensity of solar radiation. Solar thermal cooling systems are still not very affordable for decentralised use. Also see Chapter 1 of this manual for the details of the case study in Angola where vaccinations for livestock are stored in solar driven refrigeration units.

The lack of proper refrigeration limits the export of dairy products to neighbouring markets in sub- Saharan Africa, since dairy products need to be cooled within four hours after production to fulfil international safety standards. Losses can reach up to 50% of milk production due to the absence or interruption of the cold chain. A biogas-powered refrigerator running on cow manure for feedstock has been developed to help milk supply meet demand. The manure produced by one cow creates enough biogas to refrigerate the milk produced in one day, and enough biogas remains for lighting and cooking purposes (Powering Agriculture MOOC Sustainable energy for food https://poweringag.org/mooc).

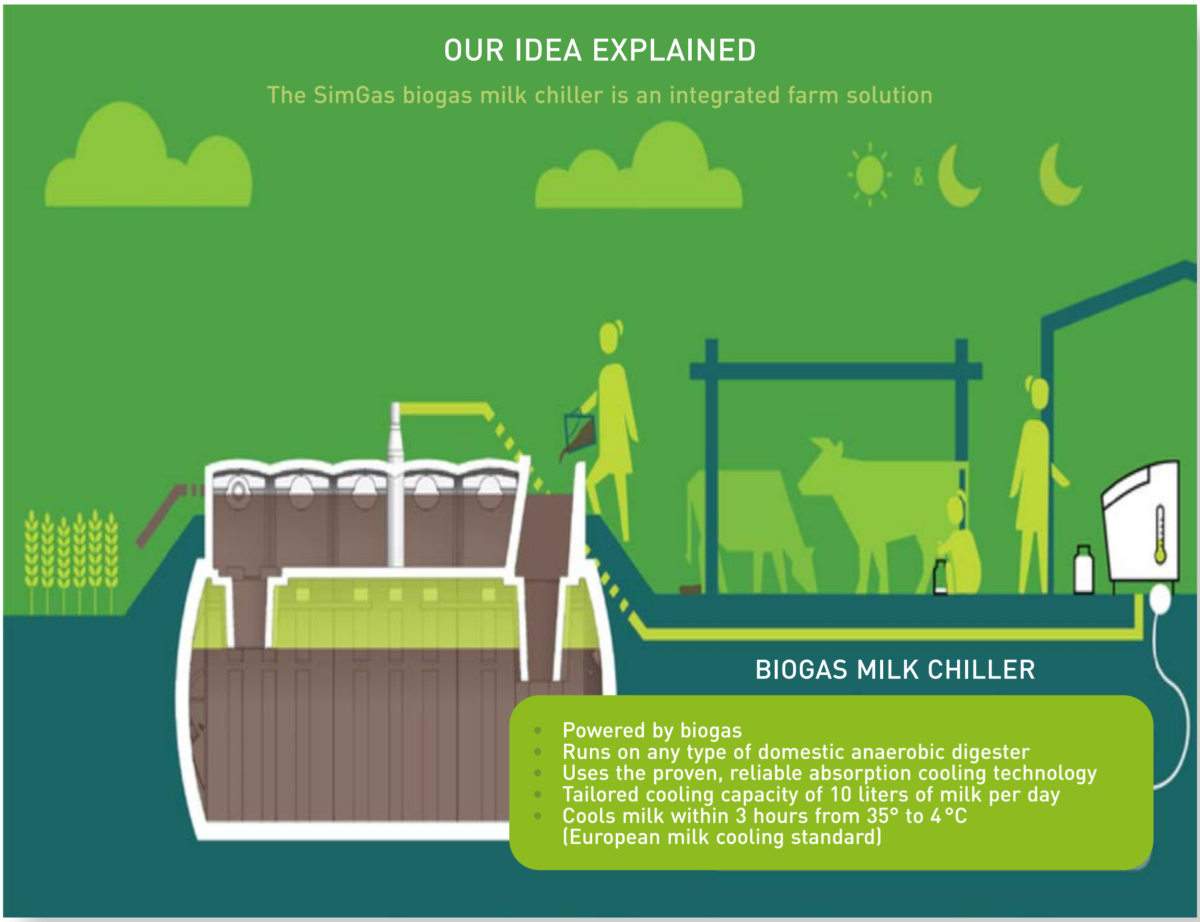


Figure 25 - Biogas refrigeration (Source https://challenges.openideo.com/challenge/agricultural-innovation/improve/biogas-powered-milk-chiller-for-small-scale-dairy-farmers-in-eastern-africa/comments)

These are just some of the approaches that have been adopted and implemented to deal with situations where access to constant and affordable energy along agro-food chains is a challenge. These ideas have been implemented successfully in many different remote rural communities and in varying geographical, political, economic, social and cultural situations with a great deal of success. These ideas demonstrate innovativeness on the part of the developers to realise energy transitions and to improve energy efficiency at all points along agro-food chains.

More details can be obtained by visiting these Web sites:

- International Energy Agency www.iea.org/topics/renewables/
- IRENA www.irena.org/publications
- FAO www.fao.org/energy/home/fr/ available in English, French and Spanish
- GIZ www.giz.de/en/html/index.html

3.3.3. Transport and distribution

The transport and distribution sector are currently practically fully dependent on fossil fuels. Reducing this dependence is crucial for avoiding climate change. The three main renewable energy sources used in these sectors are:

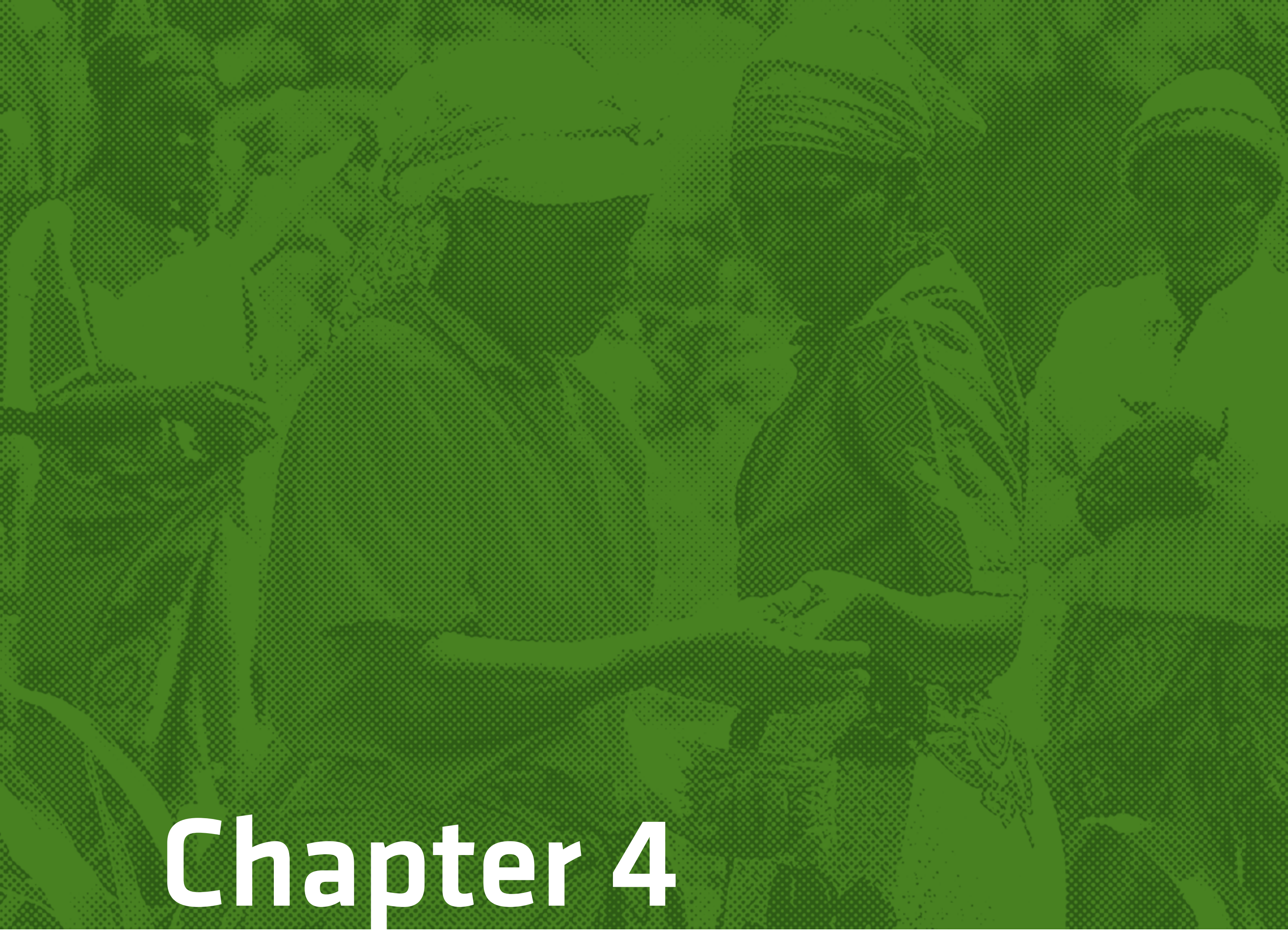
- 100% liquid biofuels, but these biofuels can also be mixed with fossil fuels,
- Biogas that is upgraded which involves the removal of water, carbon dioxide, hydrogen sulfide, and other trace elements. This upgraded biogas is comparable to conventional natural gas and thus suitable for vehicles that run with Compressed Natural Gas (CNG) and
- Renewable electricity, for example, the use batteries to store solar energy for battery-electric vehicles.

The primary renewable energy in the transport and distribution sector are liquid biofuels such as corn ethanol, soy biodiesel, wheat ethanol, sugarcane ethanol and palm oil biodiesel, but electrification of transport and distribution sector continues to grow (REN21, 2017).

In the United States, the use of biogas increased the past few years while in Europe biogas continued to gain shares of the transport fuel mix. The developments in other regions of the world has remained limited.

New developments in these areas can be viewed by visiting the following Web sites:

- Renewable energy world www.renewableenergyworld.com
- International Energy Agency www.iea.org/topics/renewables/
- IRENA www.irena.org/publications



Chapter 4

Case study

LEARNING OBJECTIVES

At the end of this case study, the learner should be able to:

- Analyse a situation close to reality.
- Propose the measurements or analysis to be carried out to make a diagnosis.
- Determine all the causes, direct or indirect, of a loss of energy on the basis of the theoretical knowledge acquired and make relevant calculations.
- Propose a set of suitable solutions for the sustainable improvement of energy use.
- Draw up a coherent action plan to establish a sustainable energy management.

4.1. WHY A CASE STUDY?

Working based on the description of a hypothetical case will never replace your professional experience forged in the field and through contact with the everyday lives of farmers. However, it is possible to **acquire, from an example drawn from situations already encountered, methodological principles** to analyse the situation, to determine the nature and origin of certain problems that may be encountered by farmers, and to be able to propose workable solutions that are efficient, cost-effective and compatible with sustainability goals.

Here is an exercise to guide you!

A case study should not be used to propose a 'ready-made recipe' whose ingredients would always result in the same solutions to be recommended to farmers. On the contrary, it should enable you to **understand the complexity of the situations that may exist and which require a case-by-case approach**, with appropriate solutions suited to each situation and to the resources available locally. **It must help the farmer to understand the 'why' of their problems and to determine themselves 'how' a lasting improvement in the situation is possible**, by weighing up the costs and benefits of each theoretical solution.

How can you use this case study to review the various aspects of sustainable energy management and apply what you have learned to a case that might be encountered in practice?

The case study consists of four parts, which are as many steps in the exercise to be carried out:

1. A scenario: by reading a text, it will be necessary to identify information that is useful to understand a situation that a horticultural company might encounter (in this case, in terms of energy use). In order to refine the diagnosis, it may be necessary to propose measurements or analyses.
2. An analysis of the situation: in order to identify the causes and propose solutions for the company, it will be necessary to analyze the data and to link the described practices to the problems encountered (nature, origin, interaction between observations) and to measure the gap existing with the objectives of the company.
3. Identification of appropriate solutions: an inventory of solutions that should be appropriate to address each identified problem separately.
4. A proposal for an action plan for the company: it will be a question of establishing an implementation strategy integrating the solutions chosen, in order to improve the situation sustainably: maintain or improve energy management.
5. Identify the specific Energy Objectives and determine how to monitor them.

To fully benefit from this case study, **you should follow the guidelines and perform each step as a personal exercise**, referring to the theoretical aspects set out in the handbook, and consulting the relevant websites and resources mentioned in this handbook.

At each step, you will have instructions, and in Annex 1. Spreadsheets Excel document **the solution.** You will see the following message:

'Have you completed your part of the exercise? Well done! Now compare your result to the proposed solution, identify the differences and try to see why your result differs from these proposals. But perhaps you have thought of a new and/or a better proposal? Write your analysis of the results, and your personal perception, in a few lines: this will help you to retrace the reasoning behind your strategy at the end of the exercise'.

Tip before you start: Print the pages of this chapter to make your work easier.

Remember: list of tasks to do in this case study!

Task 1. Explain what Renewable energy is
Task 2. Explain what an Energy audit is
Task 3. Explain which systems will be assed
Task 4. List the documents required to collect energy data
Task 5. List steps that need to be taken into account for establishing energy balance
Task 6. Make a list of Energy consuming machines, equipment and tools
Task 7. Complete the Energy consumption and Cost table
Task 8. Calculate the consumption in kWh
Task 9. Make a Bar chart on Energy consumption and costs
Task 10. Draw conclusion from Bar chart
Task 11. Make a Pie chart on Energy consumption and costs
Task 12. Conclusion on Pie chart
Task 13. Identify energy use
Task 14. Calculate consumption in kWh/Year including share of Total, Energy use and input
Task 15. Make a Pie chart on Electricity and Fuel uses
Task 16. Draw conclusion from Pie chart
Task 17. List points of consideration in relation to Company's energy consumption
Task 18. Calculate EnPI Energy consumption and Costs
Task 19. List main equipment to investigate
Task 20. Identify energy saving opportunities
Task 21. Identify Energy guzzlers: A. COLD STORAGE ROOM
Task 22. Identify Energy guzzlers: B. LIGHTING
Task 23. Identify Energy guzzlers: C. BLAST FREEZER
Task 24. Calculate the financial gain or loss at the end of year Five
Task 25. Advise Jane in terms of buying a new tractor
Task 26. Recommend a renewable energy source
Task 27. Explain what the benefits of Solar electricity are
Task 28. Demand cold storage room
Task 29. Estimate the Solar system properties
Task 30. Estimate the System Cost
Task 31. Develop an Energy action plan
Task 32. List the activities per priority area and advise which priority area to choose
Task 33. Explain what Energy objectives are
Task 34: Explain what Monitoring means
Task 35. Calculate the total energy savings and costs including the percentage compared to 2017
Task 36. Calculate reduction energy consumption and costs

4.2. BACKGROUND

4.2.1. Introduction (the scenario)

Jane Browne is the manager of the family company **Fresh and Tasty** and a member of a farmers' cooperative. It is a medium-sized company (about 15 ha) established on the outskirts of a large city and close to a few villages where a good part of its vegetables is sold throughout the year. The company is 30 km away from its main local market (a large town) and the large sea port from where its premium products (frozen green beans, cassava and okra, and dried tomatoes) are sent to Europe.

Jane has to pay the staff of eleven persons on her farm. One the farm there is canteen where Jane's husband cooks daily for all staff on petrol stoves. In the canteen they have a freezer where they store frozen fish and meat and a small fridge for other ingredients.

Jane is very concerned with the increase in energy prices in the country: in 2014, the electricity tariff was $0.08 per kWh, now it is already $0.12. The price for a litre of diesel and petrol have increased as well in the last few years, from $0.70 and $0.80 to a stunning $1 and $1.1 per litre of diesel respectively petrol today. This is why Jane is seeking help to reduce the farm's energy expenses.

Another major issue Jane has to deal with is that at least 3 times a week she has no electricity for 4-6 hours and sometimes longer. This causes the frozen products to thaw which endangers product quality and eventually leads to spoilage of these products. Even the cold stored fresh produce lettuce and bell pepper quality and shelf life decreases. The product and especially the financial losses are a huge setback for this family company. The financial loss is about $20,000 per year.

4.2.2. Cultivation and harvesting

Fresh and Tasty Company produces some of its products (okra, green beans and cassava) in the open field. They allocated 14 ha for open field production. One hectare is used for growing bell pepper, tomato and lettuce in shade houses. The company is located in Silver Springs, an area with heavy clay soils and a dry season that lasts for six to seven months of the year. The main water source is a reservoir constructed on site, which at maximum capacity during the rainy season holds 10,000 m^3 of water. The water is pumped into three storage tanks each with a capacity of 2,500 m^3 and each serving 5 ha. The water is then pumped to the fields with diesel pumps (a total of four pumps). The crops in the open field are irrigated using drip irrigation. In the shade houses hydroponic systems are installed. Two tractors are used for land preparation and inter-crop weed control, and for transporting the harvest from the open field and shade houses to the packing house. They also have an additional 2 brush cutters used for weed control.

The Fresh and Tasty Company produce 10 tons of bell peppers, 40 tons of tomatoes and 6 tons of lettuce per year in the greenhouses and 100 tons of cassava, 50 tons of green beans and 25 tons of okra per year in the open field.

Figure 1 - Electric water pump for shade house

4.2.3. Packaging house

In its packing house, it sorts and packs products for local and export markets. At the packaging house, the tomatoes are dried using drying tables put out in the sun every morning and brought in doors at night; 10 tons of dried tomatoes are produced each year. However, the process is slow and a lot of the tomatoes spoil and have to be thrown away. The staff spends a lot of time each day carefully sorting through the dried tomatoes; up to 5% (0.5 tons) of the dried tomatoes are not fit for the market. The drying of tomatoes can only be done during the dry season, with their current system.

The okra and green beans are packed and placed in the blast freezer. After the boxes reached -30 °C they are placed in one of the other freezers.

The lettuce and bell pepper are packed and placed in the cold storage room at a temperature of 2 °C.

Reefer trucks are used to take the produce to market in the town 30 km away, as well as the nearby villages.

4.2.4. Energy using items

Here is a list of all the energy uses of the Fresh and Tasty Company:

- Two diesel tractor-used for transporting produce form the field and shade houses to the company's pack house. As well as cultivation on farm.
- Two (2) brush cutters for weed control
- Four (4) diesel water pumps for the open field
- Two (2) electric water pumps for the shade houses
- Electricity is used for lighting for the pack house, running the 1 blast freezer, 2 freezers, 1 cold storage room for the storage of the lettuce and bell peppers and small office equipment such as 2 computers, 2 electronic scales, equipment for packing and labelling the fresh, dried and frozen produce, as well as the security lighting for the pack house and its perimeter.
- Two reefer trucks for taking produce to the town, villages and sea port.
- 1 freezer and a small fridge in the canteen
- 3 petrol cooking stoves

Jane has to buy diesel for the pumps, tractors and trucks, petrol for the brush cutter and the stoves in addition to the farm inputs-seeds, fertilizer, pesticides, etc. She is also concerned about the high electricity bill for the packing house. A lot of people have told Jane that she can reduce the cost of energy by using renewable energy. Unfortunately, Jane has no clue what renewable energy means but wants to know about it to find out if this is the way to reduce her electricity bill.

Task 1: Explain what Renewable energy is

Could you explain to Jane what a renewable energy is?

Friends advised Jane to hire an energy expert to perform an energy audit to evaluate the current situation on the farm. Jane wants to know so much more about this energy audit but her friends couldn't explain more.

Task 2: Explain what an Energy audit is

Could you explain to Jane what an energy audit is?

4.3. PROVIDE AN ANALYSIS OF THE SITUATION

We now have the background information about Jane's farm, where do we start? You may remember from earlier chapters the formula used to improve energy efficiency depending on the '**energy balance'** of an enterprise. This formula is used to determine if the switch from fossil fuel to RE technologies or a mixture of both is required to improve the energy efficiency of the farm operations.

To recap, "an **energy balance** is the quantification of all input energy (e.g. fuels, electricity, heat) and output energy (e.g. lighting energy, water heating, waste heat) in a given system boundary". It is a useful tool to analyze the energy uses and losses of a system (e.g. building, production process).

Remember also the rule: **"If you don't know how much you spend and where, on which type of energy, how can you identify savings?"**. You can't manage or invest in a system unless you know how much energy is being lost from the system. Again we go back to the first law of thermodynamics: **"Energy can neither be created nor destroyed"**.

The action of human or machines involves the conversion of energy from one form of input into two or more forms of output. One of those forms is useful energy, the others are energy losses. The main objective here is to reduce the technical losses by changing the systems in a cost-effective manner. As a result the management of energy systems has to consider three challenges:

1. How to specifically define the system under consideration
2. How to quantify the energy flows into and out of the system and
3. The awareness of employees regarding the purpose of energy management

4.3.1. Challenge 1: Defining a system boundary

Remember that a ‘system’ is anything consuming energy such as a building, area in a building, an operating system, the collection of equipment or piece of equipment around which we can draw an imaginary boundary. The main concern for energy accounting is not the area within the boundary but instead the energy streams that **cross the boundary**. This is the energy that must be accounted for so that is why the system boundary must be very clearly defined.

Task 3: Explain which systems will be assed

On Jane’s farm which systems will we assess?

4.3.2. Challenge 2: Quantifying energy flows

This second challenge is more difficult to assess. We have to collect the energy flow data from various sources taking into consideration measurements on equipment. Some of the energy flows can’t be directly measured though as mentioned in an earlier example – heat loss through a wall of a building or in the air vents for example; however, this must also be included by indirect measurements (here, the inside and outside temperatures) and calculations.

Task 4: List the documents required to collect energy data

Which documents should Jane use to collect energy data?

4.3.3. Challenge 3: Awareness of employees

The awareness of the employees as to the purpose of energy management is the third challenge. Successful energy management and the accuracy of the data depend on employees being aware of the following points:

- The company's energy policy, objectives and targets
- How individuals themselves can contribute to energy management
- Have information on energy consumption and trends within the company
- The need for compliance with legal and other requirements
- Areas for improvement
- The financial and environmental advantages of energy management
- Who to contact for further details/information

To deal with this challenge one can consult the ISO 50001, where it relates to internal communication requirements for the successful management of energy for agri-food enterprises. Training programmes are another good avenue. These must of course be well designed to develop the necessary competence for energy management in employees, as well as their awareness of the same.

4.4. STEPS TOWARDS ESTABLISHING AN ENERGY BALANCE

Task 5: List steps that need to be taken into account for establishing energy balance

For practical application of establishing an energy balance, which steps must be take into account?

To better understand the importance of an energy balance in determining **"you have to know what you have before you can manage it"**.

4.4.1. Make a list of all energy inputs

Instruction:

On a spreadsheet, try to **list all energy inputs that are used on the farm** (without reading further).

Go back to 4.2. Background and read the scenario presented for Jane's farm.

In Task 4 you already listed the relevant documents that contain energy data. Before you start collecting and analysing data, check if the following documentation is available in the company:

- Records on energy consumption and consumer structure (e.g. machinery lists);
- Plans, programmes, audit reports, measurements, etc.
- Meter readings from utility company etc.
- Bills, invoices from utility companies, fuel suppliers etc.

Data on the annual consumption as well as costs have to be collected separately for each type of energy. These data are available in the invoices of the energy suppliers (electricity, district heating, gas) or suppliers of heating oil or diesel as well as in records of the in-company petrol station or electricity plant, etc.

Data should be collected separately for the following types of energy: electricity (energy supplier), in-plant electricity generation (hydropower, photo voltaic); natural gas, heating oil (heavy, light, extra light), fuels (diesel, petrol), biomass, solar power and district heating.

Jane will need to list the energy using equipment.

For each part of the process/production identify what is consuming energy:

- Production: ....
- Harvest: ....
- Transport: ....
- Post-harvest: ....
- Packaging: ....
- Export: ....

Task 6: Make a list of Energy consuming machines, equipment and tools

Table 1: Enery consuming machines, equipment and tools

Could you complete this table for Jane?

	Use		
Processes	**Electricity uses**	**Diesel fuel uses**	**Petrol fuel uses**
Production			
Harvest			
Transport			
Post-harvest			
Packaging			
Export			

Very good, now check what you have written against what has been prepared in Annex 1. Spreadsheets Excel document.

4.4.2. Identify where significant amounts of energy are used

Instruction:

Identify where significant amounts of energy are used. This time around we want to capture the percentage of each energy type consumed.

Jane collects all the fuel and electricity data from utility bills and supplier invoices from the last four years. **She collected the following documents:**

THE ENERGY COMPANY CC

Electric bill

Invoice number: 1222334

Company:	Fresh and Tasty	Client:	Jane Browne
Address:	Bean street 4	Year billing overview:	2017

Month	Usage in kWh	Costs in US$
January	17,200	2,064
February	17,750	2,130
March	17,291	2,075
April	17,291	2,075
May	17,200	2,064
June	17,250	2,070
July	17,899	2,148
August	17,200	2,064
September	17,122	2,055
October	17,100	2,052
November	17,129	2,055
December	17,068	2,048
Total	207,500	24,900

Figure 2 - Electric bill

THE ENERGY COMPANY CC

Fuel bill

Invoice number: 165678788999

Company:	Fresh and Tasty	Client:	Jane Browne
Address:	Bean street 4	Year billing overview:	2017

Month	Diesel in litres	Costs in US$	Petrol in litres	Costs in US$
January	790	790	113	124
February	755	755	112	123
March	745	745	111	122
April	850	850	110	121
May	726	726	100	110
June	810	810	107	118
July	755	755	100	110
August	850	850	95	105
September	800	800	83	91
October	790	790	115	127
November	795	795	109	120
December	834	834	95	105
Total	9,500	9,500	1,250	1,375

Figure 3 - Fuel bill

She then uses a simple Spreadsheet to list them (Excel document: "Energy management Case Study").

For each energy input we identified what:

- we want to know
- the source of measurement is,
- the accuracy level,
- the amount consumed,
- the cost,
- the share of consumption and cost.

Jane needs to use the table below to capture this information.

Please complete year 2017 based on the data provided in Figure 2. Electric bill and Figure 3. Fuel bill.

Task 7: Complete the Energy consumption and Cost table

Table 2: Spreadsheet A 3-1- section 1

Could you complete this table for Jane?

Energy-Input	Energy Source	Petrol	Diesel	Electricity	TOTAL
	Unit	litre	litre	kWh	
Measurement		Invoice	Invoice	Utility bills	
Accuracy		high	high	high	
Consumption	2014	900	8,000	204,765	
	2015	1,100	8,500	203,498	
	2016	1,000	9,000	206,751	
	2017	....	....	....	
Costs [US$]	2014	720	5,600	16,381	22,701
	2015	990	6,800	18,315	26,105
	2016	1,000	8,100	22,743	31,843
	2017	....	....	....	100%
Share of Total Consumption	2014	2.7%	27.1%	70.1%	100%
	2015	3.3%	28.3%	68.4%	100%
	2016	2.9%	29.2%	67.9%	100%
	2017	....	....	....	100%
Share of Total Costs	2014	3.2%	24.7%	72.2%	100%
	2015	3.8%	26.0%	70.2%	100%
	2016	3.1%	25.4%	71.4%	100%
	2017	....	....	....	100%

In order to compare the different units of energy better, they can be converted into kWh using common conversion factors:

Task 8: Calculate the consumption in kWh

Could you complete this table for Jane?

Table 3: Spreadsheet A 3-1- section 2

Consumption [kWh]						
Energy Source	Unit	Conversion factor[3 8] in kWh	2014	2015	2016	2017
Electricity	kWh	1	204,765	203,498	206,751	....
Diesel	Litre	9.9	79,200	84,150	89,100	....
Petrol	Litre	8.85	7,965	9,735	8,850	....
Total			291,930	297,383	304,701	....

Jane needs to draw a bar chart for the period 2014-2017 that presents both the energy input in kWh and costs in US$.

Task 9: Make a bar chart on energy consumption and costs

Make a bar chart with the information Jane has captured

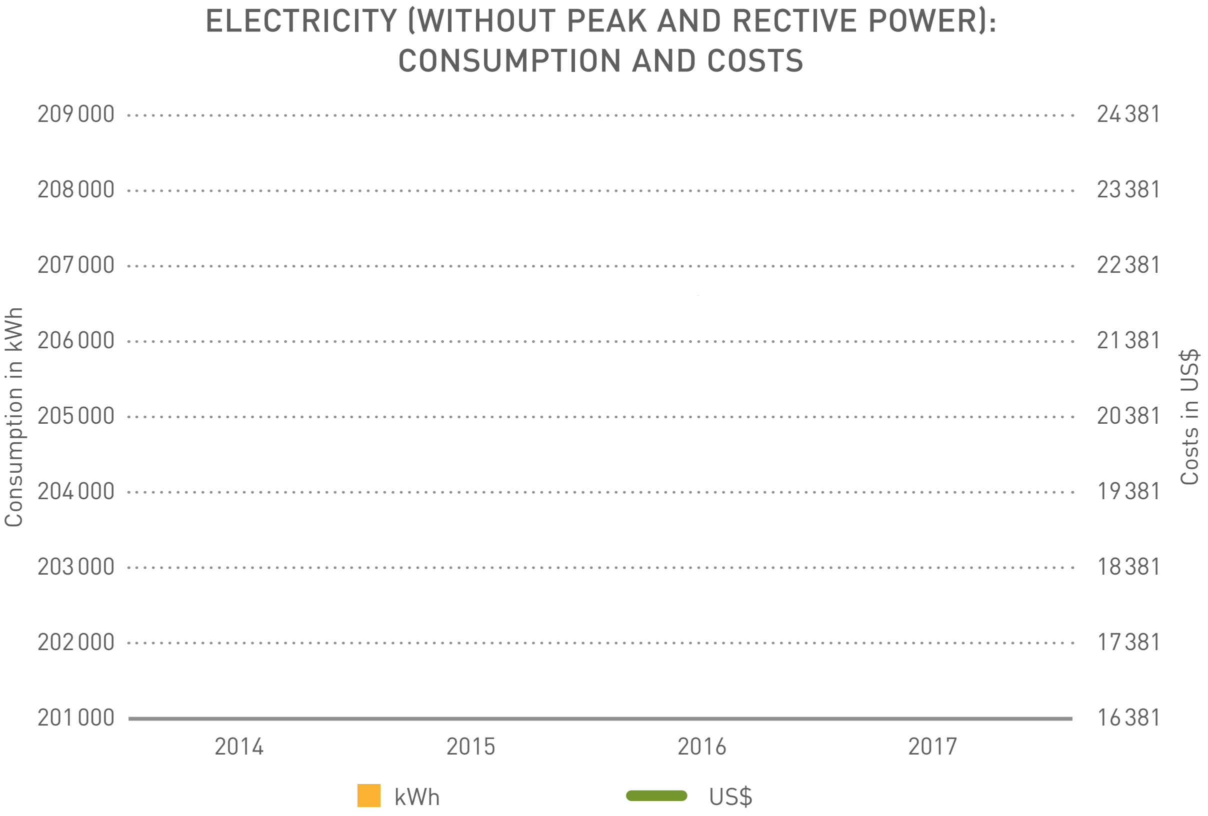


Chart 1 - Spreadsheet A 3-1- section 3

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8 Source: Gemis Datenbank 4.81 (2013).

Task 10: Draw conclusion from Bar chart

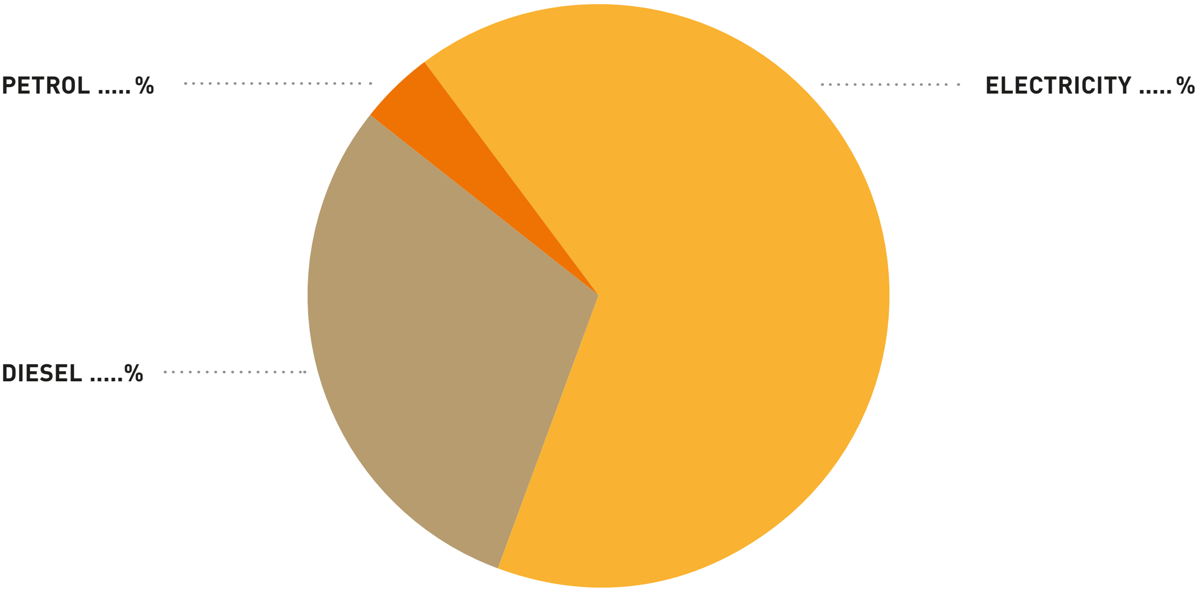
Which conclusion can she draw from this bar chart?

Jane needs to know what the share of consumption is to identify the largest share of energy input. Therefore, she needs to make a pie chart per year.

Task 11: Make a pie chart on energy consumption and costs

Make a pie chart with the information Jane has captured

SHARE OF CONSUMPTION (2017)



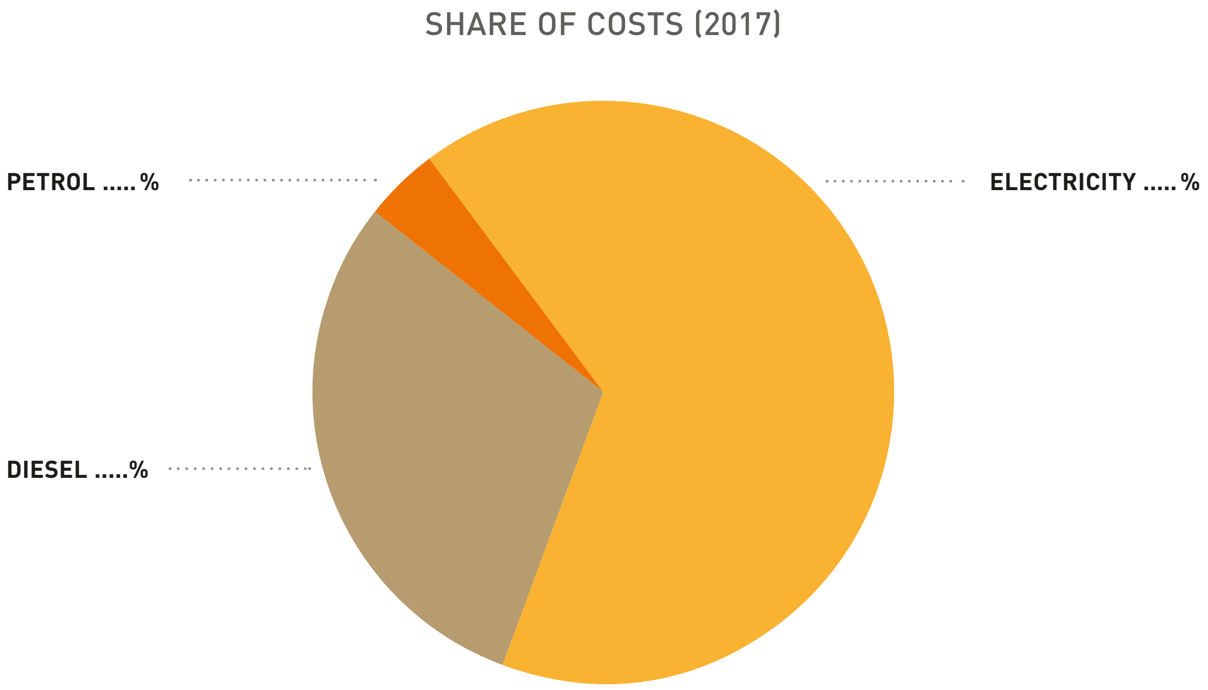


Chart 2 - Spreadsheet A 3-1- section 4

Task 12: Conclusion on pie chart

Which conclusion can Jane draw from the pie chart?

4.4.3. Calculate the amount of energy used per equipment

With the help of the energy charts established before, Jane knows that electricity is the company's highest expense in terms of energy. Also, she sees that the electric consumption has increased continuously over the past years and that the expenses have too, whereas the expenses for diesel and petrol are much lower and have increased more moderately. Thus, Jane already can say that looking at the electrical consumption- what is drawing how much electricity? – is her priority.

Where is the energy being used?

Significant energy uses are machines, equipment and tools which actually use the input energy- electricity, fuels, heat- to perform work, for example electric motors, water pumps or heat boilers to provide hot water. To make the data capturing easier, Spreadsheet A3-3- to A3-9 (Annex 1. Spreadsheets Excel document) provide lists for the most usual applications. You should monitor the rated power and full-load hours. If necessary, estimate them for small machines, large machines usually have operating time meters. Then calculate the total consumption and allocate this value to consumer groups and specific applications. Use the column 'Notes' to record details on energy saving measures and any necessary renewal or maintenance work identified during the data collection.

Jane wants to know where the energy- particularly the electricity - is used, because it's the highest cost factor-.

Task 13: Identify energy use

How could Jane do that?

In Excel document: "Energy management Case Study" - Spreadsheet A3-2 the most important energy uses, their rated power, operating hours and consumption are listed. Based on her records she was able to list all energy-using equipment, calculate the number of hours per year per equipment. All in all, a total of at least 80% of the input energy should be accounted for. It is important to distinguish consumers according to their applications.

Could you help her calculate consumption per year, the share of the total, total energy use and total energy input?

Task 14: Calculate consumption in kWh/Year including share of Total, Energy use and input

Table 4: Significant energy uses - Spreadsheet A 3-2- section 1

Use	Rated Power [kW]	Average load factor [%]	Hours/ Day	Days/ Year	Hours/ Year	Consumption [kWh/Year]	Share of Total
Electricity uses						....	....
Product Freezers 1+2	8	60%	8	250	2,000	....	....
Blast freezer	50	60%	6	250	1,500	....	....
Cold storage room[9]	15	70%	24	365	8,760	....	....
Computers 1+2	1	50%	24	300	7,200	....	....
Lighting	15	100%	14	250	3,500	....	....
Small equipment for sorting, grading and packing[10]	1	70%	8	200	1,600	....	....
Water pump 1 (electric)	2,5	70%	6	200	1,200	....	....
Water pump 2 (electric)	2	70%	4	200	800	....	....
AC freezer in the canteen	2	60%	2	200	400	....	....
Fuel uses	**Rated Power [kW]**	**Average load factor [%]**	**Litres/ Day**	**Days/ Year**	**Litres/ Year**	**Consumption [kWh/Year]**	**Share of Total**
Brush cutters 1+2 (petrol)	3,8	100%	3	250	750	....	....
Water pump 1 (diesel)	2	100%	4	250	1,000	....	....
Water pump 2 (diesel)	2	100%	2	250	500	....	....
Cooking stoves 1,2,3 (petrol)	2	100%	2	250	500	....	....
Tractor 1 (diesel)	90	100%	15	250	3,750	....	....
Tractor 2 (diesel)	75	100%	10	250	2,500	....	....
Small reefer truck 3 (diesel)	55	100%	7	250	1,750	....	....
Total electricity						....	....
Total fuels						....	....
Year	2017	TOTAL ENERGY USE				....	....
TOTAL ENERGY INPUT						....	....
Share of total energy input (%)						100%	....

---

[9] Cold room (small scale, owner built) 40 m^2/ 360 kWh per day.

[10] 16 kWh/ day for Small equipment for sorting, grading and packing.

Jane needs to know where the energy is going to. Therefore, she needs to make a pie chart per year.

Task 15: Make a Pie chart on Electricity and Fuel uses

Make a pie chart with the information Jane has captured

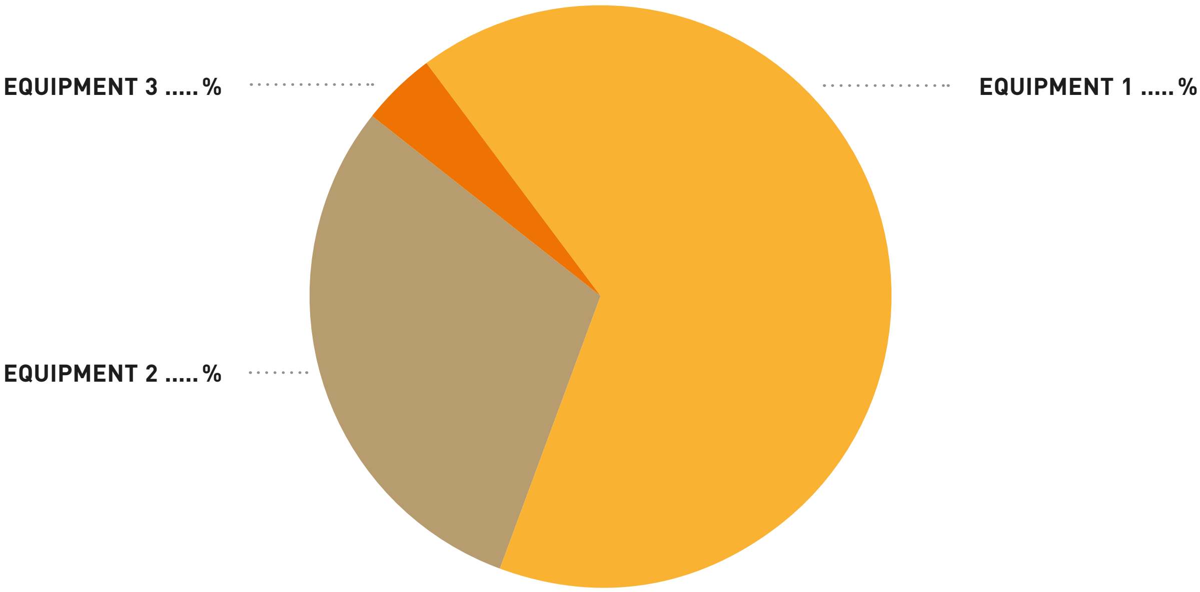

ELECTRICITY USES (2017)

Chart 3 - Electricity use - Spreadsheet A 3-2- section 2

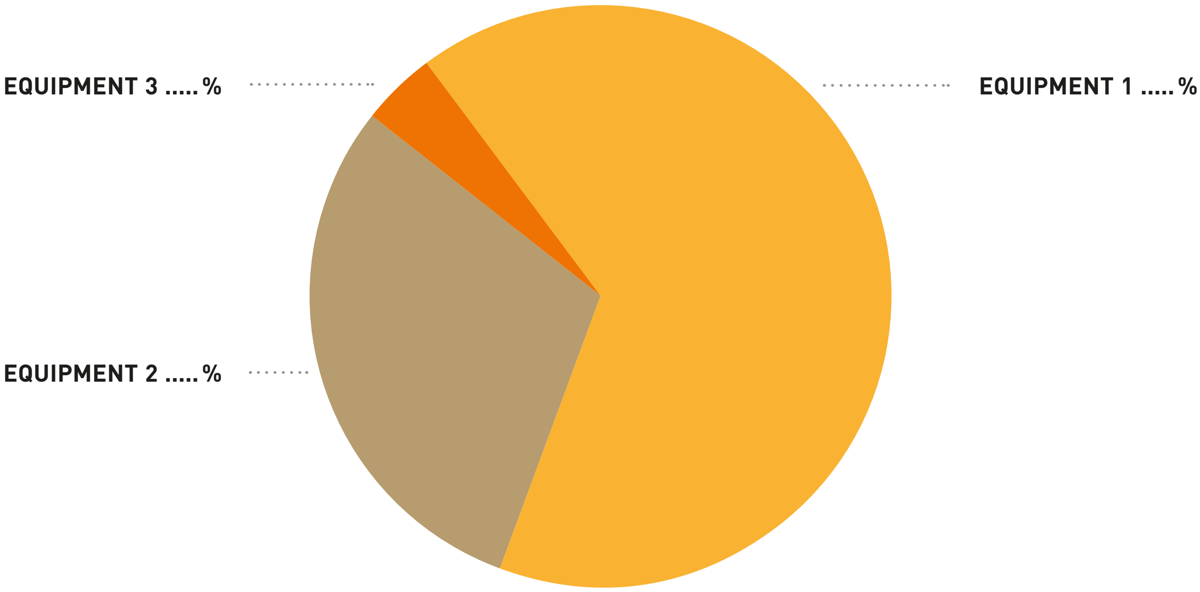

FUEL USES (2017)

Chart 4 - Fuel use -Spreadsheet A 3-2- section 2

Task 16: Draw conclusion from pie chart

Which conclusion can Jane draw from the pie chart?

4.4.4. Identify the specific energy performance indicators

For the evaluation of a company's energy consumption, reference values, the so-called energy performance indicators (EnPIs) are essential. These indicators can differ substantially depending on the type of energy or the characteristics of the company. Typical reference values are production volume, turnover, number of staff, heated surface, transported volume, mileage, etc.

Table 5: Reference values

Reference values		2014	2015	2016	2017
Number of employees	persons	8	8	10	11
Farm area	ha	10	10	12	15
Working days per year	days	250	250	250	250
Production quantity	tons	200	200	220	231

Every company should strive to reduce its specific energy consumption. For expanding companies, benchmark trends are a reliable indicator of energy efficiency, whereas overall energy consumption is not really significant.

Based on the specific energy consumption, the **energy situation** in a company can be analysed and controlled.

Task 17: List points of consideration in relation to company's energy consumption

Which points have to be considered in this situation?

EnPIs are a perfect tool for monitoring a company's energy consumption. If done regularly – say monthly – one can easily detect deviations from business-as-usual. You can use Excel-table A3-12 (Annex 1. Spreadsheets Excel document) for establishing and reporting EnPIs.

Jane is now aware of how much energy is consumed, how much she spent on energy and where the energy is being used. Also, she knows that the energy consumption has increased in the recent years.

This increase in energy can of course be appropriate because the company has produced more (higher production = higher energy consumption). However, Jane is uncertain about the real cause. In order to find out the cause of the increase in energy consumption, Jane establishes a set of EnPIs. **Could you help Jane by calculating the EnPI Energy consumption and EnPI Energy costs in the table below?**

Task 18: Calculate EnPI energy consumption and costs

Table 6: EnPI energy consumption

Could you complete this table for Jane?

	Unit	Quantity						Costs [US$]					
Energy		2014	2015	2016	2017	2018	2019	2014	2015	2016	2017	2018	2019
Electricity	kWh	204,765	203,498	206,751	207,500	………………	………………	16,381	18,315	22,743	24,900	………………	………………
Petrol	kWh	7,965	9,735	8,850	11,063	………………	………………	5,600	6,800	8,100	9,500	………………	………………
Diesel	kWh	79,200	84,150	89,100	94,050	………………	………………	720	990	1,000	1,375	………………	………………
EnPI Energy consumption	kWh/ton	………………	………………	………………	………………	………………	………………	………………	………………	………………	………………	………………	………………
EnPI Energy costs	US$/ton	………………	………………	………………	………………	………………	………………	………………	………………	………………	………………	………………	………………

4.4.5. Develop an energy action plan

4.4.5.1. Identification of appropriate solutions for saving energy

Earlier we talked about the importance of recording and documenting the energy data of equipment and machinery. Based on the collected data, their respective energy costs can be calculated and allocated to the individual consumers. In this way, the concerned departments can determine the saving potential.

Suppliers often provide reference values of energy consumption for plants and equipment (e.g. efficiency of boilers, energy consumption of refrigerating equipment, etc.). By comparing these data with the data you have collected, you can determine whether your machine runs below or above the rated efficiency. With machines, for instance, which are more than five to ten years old considerable amounts of energy can be saved by installing new microelectronics and sensor technology (e.g. frequency converters for speed control).

Based on the consumer structure, energy-saving measures can be prioritized and purchasing guidelines can be established. Potential energy efficiency measures (EEMs) should be documented in form of an energy action plan, see Excel-table A3-0 (Annex 1. Spreadsheets Excel document).

Jane wants to know how energy efficient the equipment actually is and how energy costs can be reduced.

Task 19: List main equipment to investigate

Which are the 3 main equipment Jane should investigate first?
1.
2.
3.

Task 20: Identify energy saving opportunities

How could she save energy?

1.

2.

3.

Write down your advice to Jane before reading further.

So for this, she starts with the biggest 'energy guzzlers', as we have seen before, electricity is the largest share of energy costs. The biggest users are:

A. Cold storage room
B. Lighting
C. Blast freezer

Task 21: Identify energy guzzlers: A. Cold storage room

So, Jane starts with the cold storage room. It has 40m² and cold air is supplied by a central AC-unit with 15kW electrical power. The cold room temperature setting is 2 °C. The AC unit is fairly new as it was installed only two years ago.

Jane has a good impression of the efficiency of the AC unit- however she thinks that the temperature setting of 2 °C might be unnecessary low. Usually, the optimum storage temperature for their kind of beans is 7 °C. Since she has learned that an increase in cooling temperature of only 1 °C gives an electrical energy saving of 4%, she wants to increase the set point temperature from 2 °C to 7 °C.

In total, that would give an energy saving of .... °C x ....% = ...% of the consumption of the AC unit.

As Jane has found out earlier, the consumption of the AC unit is ....kWh per year. 20% of it would be an energy saving of ....kWh per year. With an electricity tariff of $0.12/kWh, this would lead to an energy cost saving of US$............. per year- for free, because no investment is needed for that!

Task 22: Identify energy guzzlers: B. Lighting

Jane is so pleased that she found her first energy saving that she continues with the 'investigation' of the other energy guzzlers. Next, she looks at the lighting system of the packing storage area, about 300m². The area is lit by 20 high-pressure-mercury lamps of 450W each. Jane knows that the lamps are old and she suspects they have been in use for least 20 years. The light they give is not suitable anymore for a working area, they have become quite dim. Jane would like to go for the latest, energy saving LED-technology. However, she is not sure whether such an investment will pay off in time.

The installed power of the lamps is .... lamps x .... W = ... W or .... kW. The yearly running time is 3,500 hours. Thus, the annual electricity consumption is .... kW x .... = ...kWh. With the electricity tariff of $0. 12/kWh, the yearly energy costs are US$ ....

Jane now knows that she can replace the old lamps with LEDs. One LED lamp costs US$ 350. Usually, a 450W lamp can be replaced by a 150W LED-lamp to have the same amount of light in the working area as before, even at a much better brightness. Thus, the LED lamps would have only .... lamps x .... W = ... W or .... kW power and consume only .... kW x .... = ...kWh per year. Their energy costs would be US$ .... which would be a cost saving of US$ .... per year.

Calculate electrical costs of old and new lamps?

Table 7: Total power and energy costs old versus new lamps

	Qty	Power (W)	Total power (kW)	Running time (hrs)	Energy (kWh)	Tariff ($)	Electr. costs ($)
Old lamps	....	....	....	....	....	....	....
New lamps	....	....	....	....	....	....	....
						Saving	....

Could you calculate the replacement cost lamps including cost saving?

However, energy is only one cost factor in lighting. Jane has observed that she needs to replace four of the old lamps a year due to age. One lamp costs US$80. With LED, the lifetime is more than double than that of the old lamps. The yearly replacement costs of US$............ including the electrical costs (see Table 7) of US$............ are in total US$ .... for the old lamps- compared to US$............ for LED-lamps.

Table 8: Maintenance old versus new lamps

	Lifetime	Price ($)	Replacement	Maint. cost ($) p.a.
Old lamps	....	....	....	....
New lamps	....	....	....	....
			Saving	....

Could you calculate the total Cost Saving?

Table 9: Total Cost Saving

	Total energy (kWh)	Total costs ($)
Old lamps		
New lamps		
Savings		
Percentage		

Could you calculate Payback time?

Altogether, the yearly cost saving would be US$ .... This a reduction of ....%. Jane can calculate the simple payback time. As already mentioned the cost for one LED lamp is $350. The cost of installing the 20 LED lamps is US$500. The total investment which includes the installation cost is US$ .... When she divides the total investment by the yearly cost savings, she can calculate a payback time.
Please calculate the payback time in the table below:

Table 10: Payback time

	Qty	Price ($)	Installation ($)	Investment ($)
New lamps	....	....	....	....
			Divided by savings ($)	....
			Payback time (yrs)	....

Which conclusion can Jane draw from calculating the payback time?

Task 23: Identify Energy guzzlers: C. Blast freezer

Although the blast freezers in use are quite modern, Jane anyway wants to have a closer look at how efficient they are. What would you consider in terms of energy efficiency of Jane's blast freezers?

4.4.5.2. Identification of appropriate solutions for saving fuels

A. New delivery truck

Jane phones the bean farmer cooperative to see if they can offer a 'cooperative truck' for all small farmers in the neighbourhood. They are interested but they would need to have a monthly payment of $50 for the next five years from each farmer in the cooperative as a leasing fee; fuel and maintenance would be included. Jane makes the following consideration: She spends $316 on fuel per year, plus about $500 for maintenance and spare parts. If she could sell the truck for $1,000, she would have a plus of $1,816 in the first year.

Task 24: Calculate the financial gain or loss at the end of year 5

What would be the financial gain or loss at the end of year 5?

B. Replace the old tractor

The old diesel tractor is twenty years old and, with a 120 HP (90kW) motor too small for loads more than two tons. However, Jane will need a bigger tractor soon because of the planned expansion of the farm.

Before getting an offer for a new tractor, Jane analyses the consumption of the tractor again (see Table 4. Significant energy uses - Spreadsheet A 3-2- section 1). She can see from that table that the tractor uses 3,750 Litres per year of diesel fuel. Jane looks at a section of a report below of the tractor which states an average fuel efficiency:

Power Take-Off performance					
ower HP (kW)	Crankshaft speed rpm	Gal/br (l/h)	lb/hp.hr (kg/kW.h)	Hp.hr/ gal (kW.h/l)	Average atmospheric conditions
Maximum Power and Fuel Consumption					
Rated Engine Speed (PTO speed - 1006 rpm)					
115.96 (86.47)	2,100	6.82 (25.82)	0.413 (0.251)	17.00 (3.35)	
Maximum Power (2 hours)					
117.27 (87.45)	1,801	6.51 (24.66)	0.390 (0.237)	18.00 (3.55)	
Varying Power and Fuel Consumption					
115.96 (86.47)	2,100	6.82 (25.82)	0.413 (0.251)	17.00 (3.35)	Air Temperature 75°F (24 °C) Relative humidity 47% Barometer 28.86'' Hg (97.73 kPa)
102.08 (76.12)	2,170	6.33 (23.95)	0.435 (0.265)	16.13 (3.18)	
77.46 (57.76)	2,202	5.26 (19.91)	0.476 (0.290)	14.73 (2.90)	
52.03 (38.81)	2,233	4.28 (16.18)	0.576 (0.351)	12.17 (2.40)	
26.27 (19.59)	2,257	3.12 (11.81)	0.834 (0.507)	8.42 (1.66)	
1.03 (0.77)	2,267	2.05 (7.77)	13.915 (8.464)	0.50 (0.01)	

Maximum torque 407 lb/ft (552 Nm) at 1247 rpm.
Maximum torque rise 40.3%
Torque rise to 1699 engine rpm 24%

Source: http://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/442/442-073/442-073_pdf.pdf

Task 25: Advise Jane in terms of buying a new tractor

In terms of buying a new tractor, what would you advise to Jane?
Below some additional guiding questions:

- Which steps would you take to come to a decision?
- What are the advantages of a new tractor?
- What about CO_2-emission?

4.4.5.3. Renewable energy

The further Jane investigates how to save energy, the more she keeps thinking about one particular topic.

At least 3 times a week, the farm has no electricity for 4-6 hours and sometimes longer. This causes the frozen products to thaw which endangers product quality and eventually leads to spoilage of these products. Even the cold stored fresh produce lettuce and bell pepper quality and shelf life decreases. The product and especially the financial losses are a huge setback for this family company. The financial loss is about $20,000 per year.

Jane has heard from a friend that he uses renewable energy for electricity production on his farm. They discussed Jane's power outages problem and her friend recommends using renewable energy for keeping the cold storage room active during power outages, so that the produce will not go bad.

Task 26: Recommend a renewable energy source

Which renewable energy source would you recommend to Jane?

Task 27: Explain what the benefits of solar electricity are.

Could you inform Jane about the benefits of solar electricity?

Jane wonders how much solar electricity is feasible for her farm and how much it would cost. Factors that could impact her decision includes:

- How much money do I have to invest in a solar electric system?
- How much space do I have available for development?
- Does my utility provider have capacity limits restricting the size of my system?
- Do I have future plans for expansion on the farm that will add electric demanding equipment or buildings?
- Is my electric usage fairly consistent or variable?
- Do I need to provide electricity during night?
- Can I reduce my electrical demand by deploying energy efficiency?

Although one may want to generate all of the electricity with the sun, many solar electric system owners begin with a small system to supplement their main supply of electricity. A small system means fewer upfront costs and the ability to gauge how much generating capacity is necessary. In addition, generating a fraction of your usage is more economical on a kWh basis than generating closer to 100% of your usage.

Jane decides to go for a system which can provide the electricity needed for the cold storage room. However, sometimes the power outage is at night, when the sun does not shine. Luckily, solar energy from the sun can also be stored in batteries. The solar system charges the batteries during the day and during the night, electricity will be drawn from the batteries to provide for the cold storage room. Solar systems with batteries are more expensive but the benefit for Jane is surely higher.

Task 28: Demand cold storage room

As we know from Task 14. Calculate consumption in kWh/Year including share of Total, Energy use and input

Table 4, the demand for the cold storage room is .... kWh per year. However, through the energy audit, Jane has already reduced this demand by increasing the setpoint temperature. Thus, the required demand comes down to .... kWh.

Task 29: Estimate the Solar system properties

With this figure equipped, the expert can do his job of providing an offer for the solar system. The steps for estimating system properties are:

Table 11: Estimating a solar electrical system

Step	Data	Calculation
1	Identify annual kWh to be powered by the solar system	.... kWh
2	Subtract kWh reduced by implementing energy efficiency measures at the equipment	.... kWh
3	Find solar radiation at the location	For Paramaribo, Suriname it is 1,600 kWhy/kW
4	Calculate solar system power by dividing demand by solar radiation	Power = (Step 1 – Step 2) / Step 3 = ... kW
5	Multiply by 1.2 to cover system inefficiencies	.... kW X 1.2 = ... kW
6	Select solar panels and note the panel size	The expert selected 250W panels
7	Divide by the kW size of each solar panel	Step 5 * 1000/ 250W = ... panels needed
8	Calculate the needed space to install the solar panels	Approximate 10 m^2 for every kW; Step 5 * 10 m^2 = ... m^2 area needed

This is only a very basic estimation; the expert will have done it with appropriate modelling software.

Table 12: Market prices for solar electric equipment (Source: NREL, 2017)

	Utility scale >1 MW	Commercial >100 kW	Residential <100 kW
Incl. panels, inverter, BOS hardware, install labour (excl. land, tax, overheads)	US$800/kW	US$1,250/kW	US$1,800/kW
Incl. the above + batteries	US$2,000	US$2,600	US$3,200

The system costs can be estimated using the table above; these are international market prices, it is of course better to find a local supplier who can give a quote.

Task 30: Estimate the system cost

Table 13: System cost estimation

Step	Data	Calculation
1	Estimate the needed investment	From table above, a 55kW system with batteries would cost .... kW X .... US$/kW = US$.............
2	If there is any grant available, subtract it	0
3	Calculate the energy cost saving	The solar system supplies .... kWh per year; the electricity tariff is $0.12 per kWh; the energy cost saving is therefore = US$ .... per year
4	Are there any other cost savings, e.g. by production optimisation etc.?	The solar system will provide electricity when the grid power is unavailable; thus, the production loss of $20,000 per year will be avoided
5	Calculate the payback time	US$ ..../ (US$ ....+US$.............) = ... years

The simple payback time of the system would be .... years. Since solar panels have a warranty time of at least 25 years, this is a good investment. Depending on the increase of electricity and fuel prices, the payback time might even be much less.

4.4.5.4. Energy action plan

Jane and her staff have found some more opportunities to save energy and costs. She documents them in her energy action plan for monitoring and further planning. **Please help Jane complete this action plan using the information in** Excel document: “Energy management Case Study” - Spreadsheet A3-0:

Task 31: Develop an energy action plan

Table 14: Energy action plan

Topic	Action (A)	Responsible	Deadline	Investment (US$)	Status	Savings			Payback [years]
						ENERGY (kWh)	CO_2 (tons)	PROFIT (US$)	
Refrigeration	Increase the set point temperature from 2 °C to 7 °C in the cold room.	Jane	May 2017	0	100%	....	10,4	....	....
Lighting	Change 20 old metal-halide-lamps to LED lamps.	Jane's husband	Oct 2017	7,000	75%	....	11,9	....	....
Ventilation	Retrofit the two 7.5kW-fan motors with variable speed drive (VSD)	Jane	Dec 2017	3,000	50%	....	8,5	....	....
Transport	Investigate if the bean farmer cooperative can provide one new delivery truck for all our small farms so that we can sell our reefer truck and save the fuel	Jane's father	1 Feb. 2018	0	0%	....	2,3	....	....
Transport	Our tractor is almost 20 years old and too small for expansion- request an offer from 'Brunos Tractor Sales & Repair' for a new, bigger tractor (maybe it has less fuel consumption?!)	Jane's father	15 Feb. 2018	cannot say yet	0%	....		....	....
Renewable energy	'Smith Solar Works' made us a proposal for using a 55kW solar PV system to power the cold storage room- we can reduce our production loss!	Jane	30 March 2018	175,161	50%	....	41,2	....	....
Awareness	There are these nice stickers available for download which say 'Lights out' and 'Keep doors closed' and other things to save energy- we should put them for all staff to remember to be energy-conscious!	Jane	1 Jan. 2018	50	0%	....	1,1	....	....
	Total			.....		.....	75	.....	

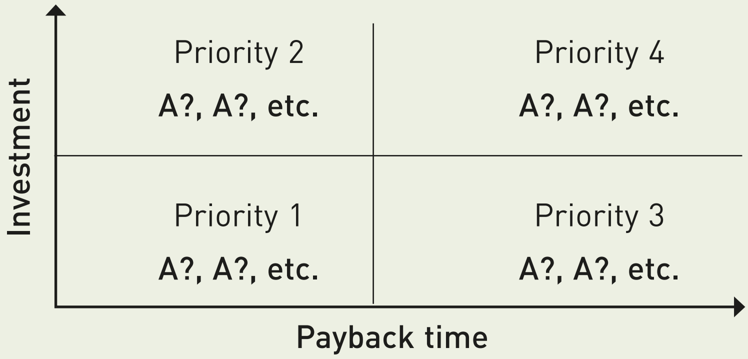
It is important to set yourself priorities when implementing energy saving measures- you can't do all at once!

- Priority 1: low investment, low payback time
- Priority 2: high investment, low payback time
- Priority 3: low investment, high payback time
- Priority 4: high investment, high payback time

Task 32: List the activities per priority area and advise which priority area to choose

Fill in for Jane which of the following Activities (A1 to A7) fits in each priority areas

- A1: Increase the set point temperature from 2 °C to 7 °C in the cold room.
- A2: Change 20 old metal-halide-lamps to LED lamps.
- A3: Retrofit the two 7.5kW-fan motors with variable speed drive (VSD)
- A4: Investigate if the bean farmer cooperative can provide one new delivery truck for all our small farms so that we can sell our reefer truck and save the fuel
- A5: Our tractor is almost 20 years old and too small for expansion- request an offer from "Brunos Tractor Sales & Repair" for a new, bigger tractor (maybe it has less fuel consumption?!)
- A6: "Smith Solar Works" made us a proposal for using a 55kW solar PV system to power the cold storage room- we can reduce our production loss!
- A7: There are these nice stickers available for download which say "Lights out" and "Keep doors closed" and other things to save energy- we should put them for all staff to remember to be energy-conscious!



Which priority area should Jane choose?

4.4.6. Identify and monitor energy objectives

Jane needs to identify energy objectives but what are energy objective?

Task 33: Explain what energy objectives are

What are energy objectives?

Based on identified opportunities for improvements, an enterprise can now identify realistic energy objectives and monitor these objectives. Jane has no clue what monitoring means. Please explain to Jane what monitoring means.

Task 34: Explain what monitoring means

What does monitoring mean?

An easy way to set an energy objective is to set a target for an EnPI- say to lower specific energy consumption for producing one ton of product over time.

Jane's plan for the future of her farm includes expanding the production to be able to export the beans. Since she now knows the cost of energy – and the value of energy savings – she wants to expand with minimal energy consumption increase as possible. Based on the above energy action plan, she decides to invest in the following energy saving measures:

- Increase the set point temperature from 2 °C to 7 °C in the cold room.
- Change 20 old mercury-lamps to LED lamps.
- Retrofit the two 7.5 kW-fan motors with variable speed drive (VSD).
- Install 55 kW solar PV system to power the cold storage room.
- Put stickers to save energy and have training for the employees on energy saving techniques.

Task 35: Calculate the total energy savings and costs including the percentage compared to 2017

These measures alone will generate how many kWh in energy savings per year?
.... and in percentage compared to 2017? ....%
These measures alone will generate how many kWh in cost savings per year?
.... and in percentage compared to 2017? ....%

By the time the above measures are implemented, the total energy consumption will increase due to the following circumstances:

- a bigger tractor is needed;
- the farm land will increase and thus a bigger water pump is needed;
- thus, the production output will increase;
- it has also to be considered that the energy prices will increase further.

Having the expansion in mind she sets the following objectives using her EnPIs (Excel document: "Energy management Case Study" - Spreadsheet A3-12).

Task 36: Calculate reduction energy consumption and costs

Table 15: EnPI Objectives

Please calculate the reduction of energy consumption and energy costs and fill in the table below.

		2014	2015	2016	2017	2018	2019	2020
EnPI Energy consumption	[kWh/ton]	1,460	1,487	1,385	1,353	1,353	1,217	1,150
Reduction to baseline year 2017	%					0	....	....
EnPI Energy costs	[US$/ton]	114	131	145	155	155	124	93
Reduction to baseline year 2017	%					0	....	....
Production quantity	tons	200	200	220	231	231	240	240

So the energy objectives of the Fresh and Tasty Company are as follows:

1. Reduce specific energy consumption in kWh per ton by ....% until 2020 (from 2017)
2. Reduce specific energy costs in US$ per ton by ....% until 2020 (from 2017)

4.5. ANNEX 1: SPREADSHEETS EXCEL DOCUMENT

Task 1: Explain what renewable energy is

Could you explain to Jane what a renewable energy is?

Renewable energy is energy that is generated from natural processes that are continuously replenished. This includes sunlight, geothermal heat, wind, tides, water, and various forms of biomass. This energy cannot be exhausted and is constantly renewed.

Task 2: Explain what an energy audit is

Could you explain to Jane what an energy audit is?

An energy audit is an inspection survey and analysis of energy flows, for energy conservation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the output(s). It is the first step in identifying opportunities to reduce energy expense and carbon footprints.

Task 3: Explain which systems will be assed

On Jane's farm which systems will we assess?

- Electrical uses like freezing, chilling, computers, lighting system, water pumping etc.
- Fuel uses like brush cutter, water pumps, cooking stoves, tractors and trucks

Task 4: List the documents required to collect energy data

Which documents should Jane use to collect energy data?

- Records on energy consumption and consumer structure (e.g. machinery lists)
- Plans, programmes, audit reports, measurements, etc.
- Meter readings from utility company etc.
- Bills, invoices from utility companies, fuel suppliers etc.

Task 5: List steps that need to be taken into account for establishing energy balance

For practical application of establishing an energy balance, which steps must be take into account?

1. Make a list of all energy inputs
2. Identify where significant amounts of energy are used
3. Identify the specific Energy Performance Indicators
4. Develop an Energy Action Plan
5. Identify the specific Energy Objectives and determine how to monitor them.

Task 6: Make a list of energy consuming machines, equipment and tools

Table 1: Enery consuming machines, equipment and tools

	Use		
Processes	Electricity uses	Diesel fuel uses	Petrol fuel uses
Production	Product freezers Blast freezers Cutting machines Water pumps Computers Lights	Water pumps Tractor Reefer truck	Brush cutter Cooking stoves
Harvest	Water pumps	Tractor	
Transport		Reefer truck Tractor	
Post-harvest		Reefer truck	
Packaging	Packaging machine		
Export	Computers	Tractor	

Task 7: Complete the energy consumption and cost table

Table 2: Spreadsheet A 3-1- section 1

Energy Inputs		Date: 12 June 2018
Company: Fresh and Tasty	Author: Jane Browne	Version: 1

Section 1

Energy-Input		Measurement	Accuracy	Consumption						Costs [US$]						Share of Total Consumption						Share of Total Costs					
Energy Source	Unit				2015	2016	2017	2018	2019	2014	2015	2016	2017	2018	2019	2014	2015	2016	2017	2018	2019	2014	2015	2016	2017	2018	2019
Electricity	kWh[1]	Utility bills	high	204,765	203,498	206,751	207,500			16,381	18,315	22,743	24,900			70.1%	68.4%	67.9%	66.4%			72.2%	70.2%	71.4%	69.6%		
Heating Oil	litre																										
Natural Gas	m^3																										
Compressed Gas	kg																										
Liquified Gas	litre																										
Diesel	litre	Invoice	high	8,000	8,500	9,000	9,500			5,600	6,800	8,100	9,500			27.1%	28.3%	29.2%	30.1%			24.7%	26.0%	25.4%	26.6%		
Petrol	litre	Invoice	high	900	1,100	1,000	1,250			720	990	1,000	1,375			2.7%	3.3%	2.9%	3.5%			3.2%	3.8%	3.1%	3.8%		
Renewable Energy	kWh																										

District Heat	Wood	
kWh[1]	kg[3]	
		Total Costs
		22,701
		26,105
		31,843
		35,775
		100%
		100%
		100%
		100%
		100%
		100%
		100%
		100%

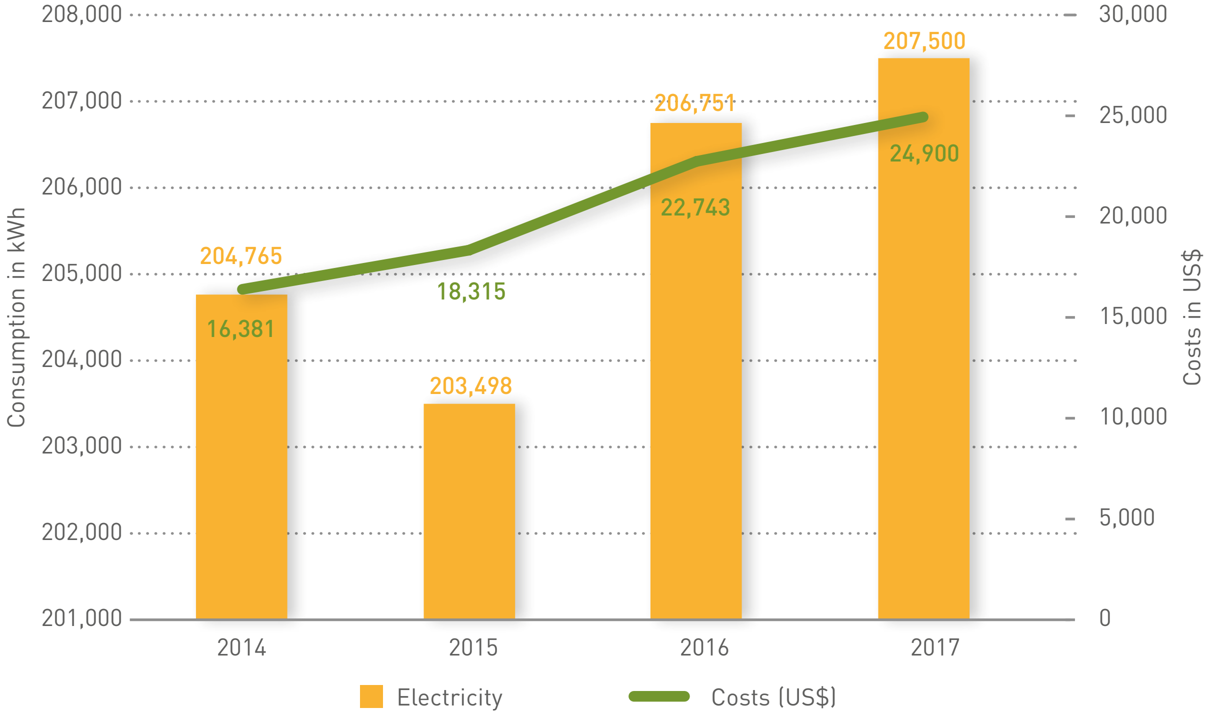
Task 8: Calculate the consumption in kWh

Table 3: Spreadsheet A 3-1- section 2

Energy Input in kWh			Fresh and Tasty			
Section 2						
			Consumption [kWh]			
Energy Source	Unit	Conversion factor in KWh	2014	2015	2016	2017
Electricity	kWh	1	204,765	203,498	206,751	207,500
Heating Oil	Liter	9.95	0	0	0	0
Natural Gas	m³	9.88	0	0	0	0
Compressed Gas	kg	12.44	0	0	0	0
Liquified Gas	Liter	12.9	0	0	0	0
Diesel	Liter	9.9	79,200	84,150	89,100	94,050
Petrol	Liter	8.85	7,965	9,735	8,850	11,063
Renewable Energy	kWh	1	0	0	0	0
District Heat	kWh	1	0	0	0	0
Wood	kg	4.5	0	0	0	0
Summe			291,930	297,383	304,701	312,613

Task 9: Make a bar chart on energy consumption and costs.

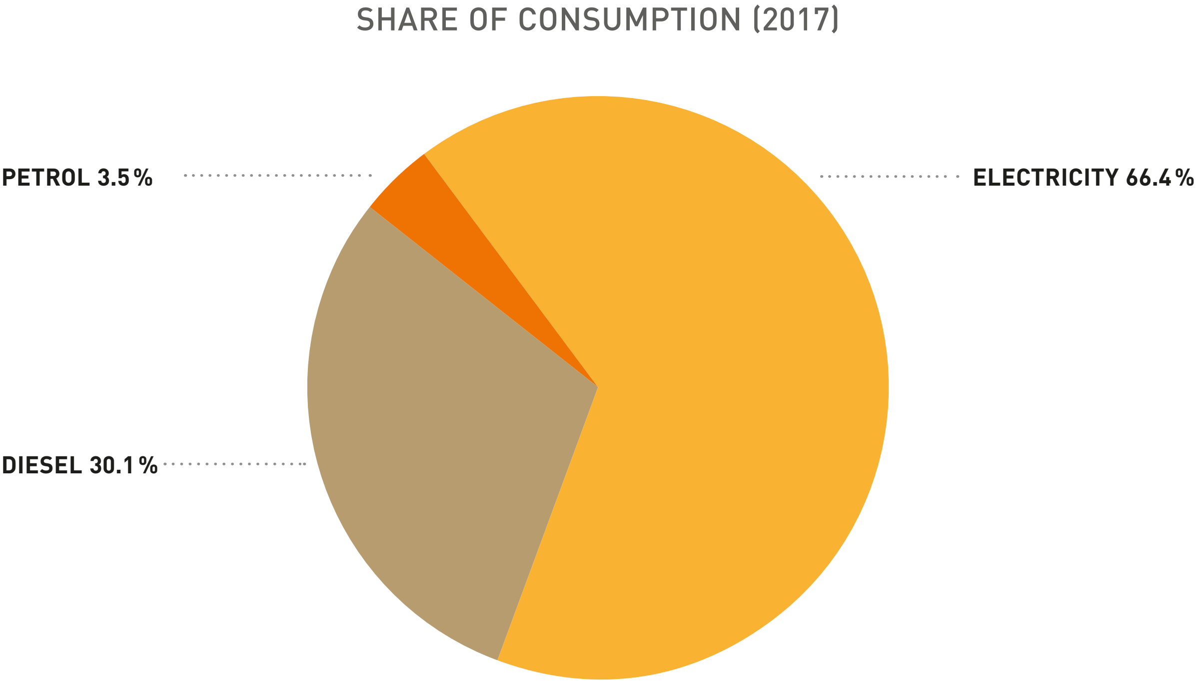
ELECTRICITY (WITHOUT PEAK AND RECTIVE POWER):
CONSUMPTION AND COSTS

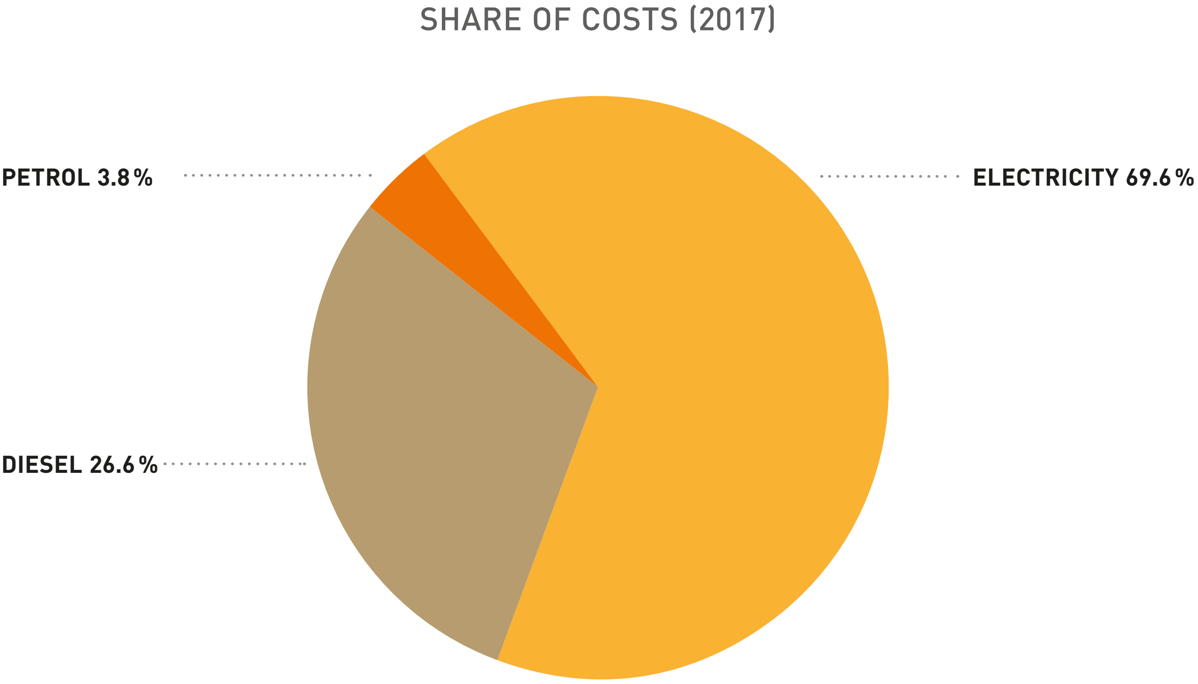


Task 10: Draw conclusion from bar chart

Which conclusion can she draw from this bar chart?
Jane **sees that the electric consumption has increased** continuously **over the past years** and that the expenses have, too.

Task 11: Make a pie chart on energy consumption and costs





Task 12: Conclusion on pie chart

Which conclusion can Jane draw from the pie chart?

Jane knows that electricity is the company's highest expense in terms of energy. Thus, Jane already can say that looking at the electrical consumption – what is drawing how much electricity? – is her priority.

Task 13: Identify energy use

How could Jane do that?

For this, she does an energy use survey of all equipment and machinery.

Jane gets the rated power in kW from the nameplates on the equipment. For the average load factor, she either used standard values from the equipment manufacturer which she found in the manuals or she discussed it with the machine operator- sometimes, these were some hard discussions but since no machine runs constantly on 100%- except for lighting- the technician believes that the values she used are close enough to reality.

Task 14: Calculate consumption in kWh/Year including share of Total, Energy use and input

Table 4: Significant energy uses - Spreadsheet A 3-2- section 1

Significant Energy Uses (SEUs)						Date: 12 June 2018	
Company: Fresh and Tasty	**Author: Jane Browne**					**Version: 1**	
Section 1							
Use	Rated Power [kW]	Average load factor [%]	Hours/Day	Days/Year	Hours/Year	Consumption [kWh/Year]	Share of Total
Electricity uses							
Product Freezers 1+2	8	60%	8	250	2,000	9,600	4.6%
Blast freezer	50	60%	6	250	1,500	45,000	21.7%
Cold storage room[11]	15	70%	24	365	8,760	91,980	44.3%
Computers 1+2	1	50%	24	300	7,200	3,600	1.7%
Lighting	15	100%	14	250	3,500	52,500	25.3%
Small equipment for sorting, grading and packing[12]	1	70%	8	200	1,600	1,120	0.5%
Water pump 1 (electric)	2,5	70%	6	200	1,200	2,100	1.0%

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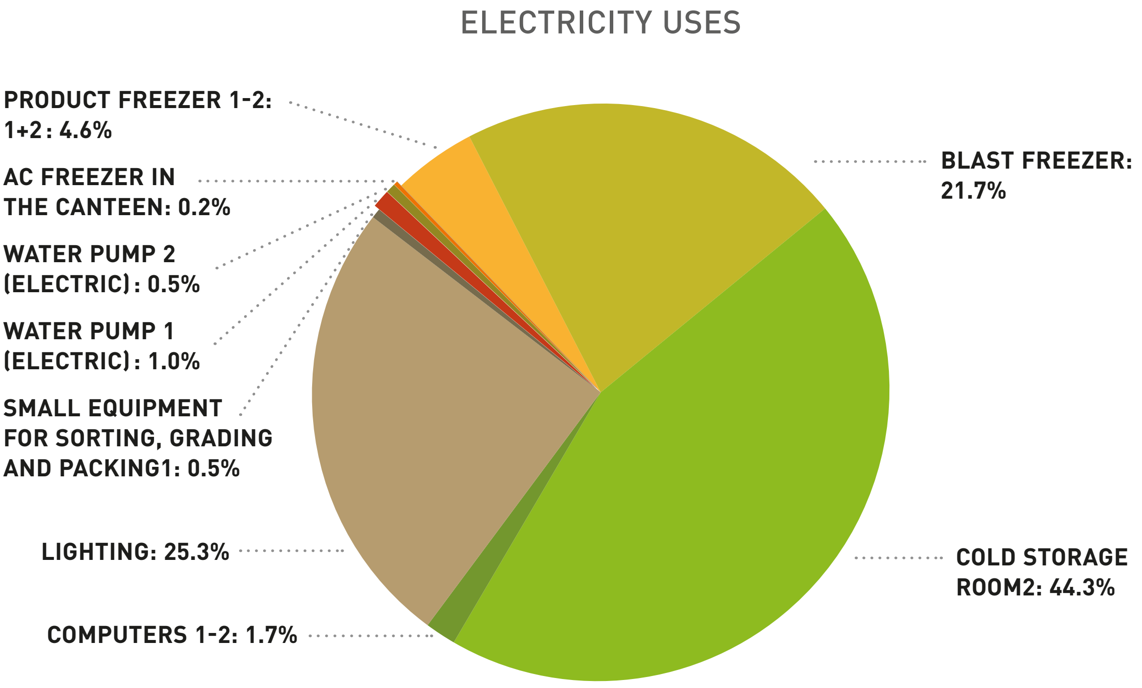
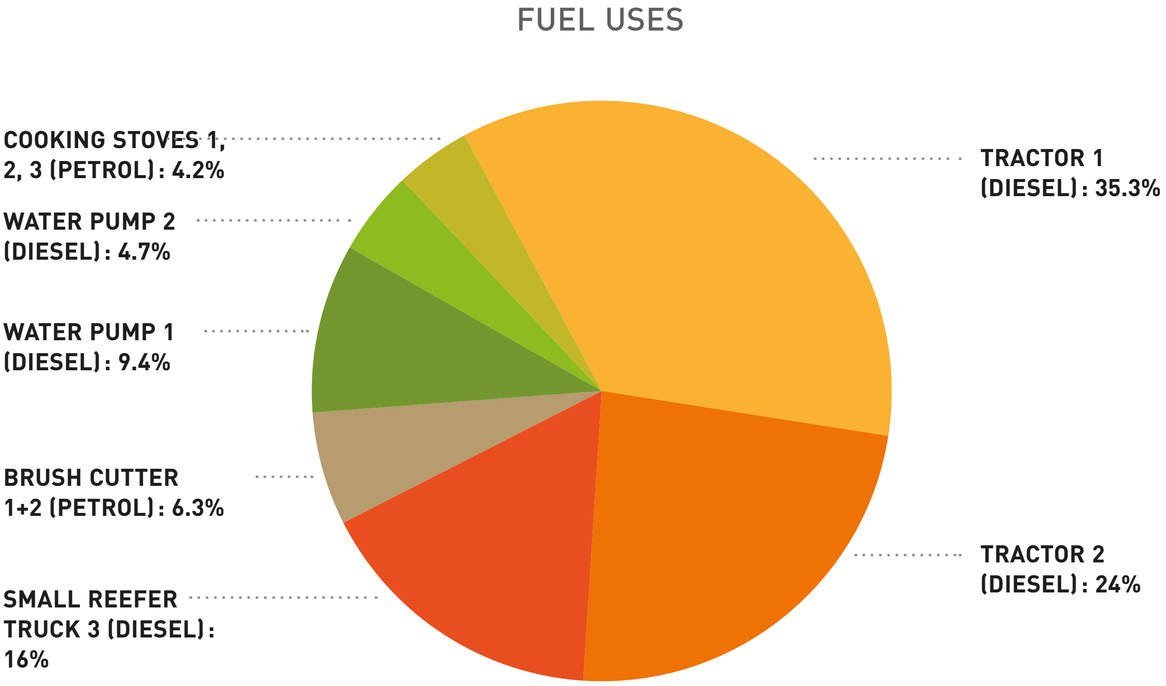
[11] Cold room (small scale, owner built) 40 m2/ 360 kWh per day.

[12] 16 kWh/ day for Small equipment for sorting, grading and packing.

Water pump 2 (electric)	2	70%	4	200	800	1,120	0.5%
AC freezer in the canteen	2	60%	2	200	400	480	0.2%
Fuel uses	**Rated Power [kW]**	**Average load factor [%]**	**Liters/Day**	**Days/Year**	**Liters/Year**	**Consumption [kWh/Year]**	**Share of Total**
Brush cutters 1+2 (petrol)	3,8	100%	3	250	750	6,638	6.3%
Water pump 1 (diesel)	2	100%	4	250	1,000	9,900	9.4%
Water pump 2 (diesel)	2	100%	2	250	500	4,950	4.7%
Cooking stoves 1,2,3 (petrol)	2	100%	2	250	500	4,425	4.2%
Tractor 1 (diesel)	90	100%	15	250	3,750	37,125	35.3%
Tractor 2 (diesel)	75	100%	10	250	2,500	24,750	24%
Small reefer truck 3 (diesel)	55	100%	7	250	1,750	17,325	16%
Total electricity						**207,500**	66%
Total fuels						**105,113**	33.6%
Year	**2017**	**TOTAL ENERGY USE**				**312,613**	
	TOTAL ENERGY INPUT					312,613	
Part de la consommation totale d'énergie (%)						100%	

Task 15: Make a pie chart on electricity and fuel uses





Task 16: Draw conclusion from pie chart

Which conclusion can Jane draw from the pie chart?

The Table above shows that electricity accounts for 66% of the energy use. The biggest electrical users are the cold storage room, the blast freezer and the lights. The tractors and the reefer truck make up 75% of the fuel use.

Task 17: List points of consideration in relation to company's energy consumption

Which points have to be considered in this situation?

In this case, the following points have to be considered.

- Has the specific energy consumption changed? Do we observe a significant increase in energy costs?
- Are the calculations of the specific energy consumption based on correct figures and assumptions?
- If the specific energy consumption has increased: What could be the reason? Which areas have expanded? Has this expansion caused the higher specific energy consumption? Have energy sources been substituted?
- If the specific energy consumption has decreased: Is the decrease due to specific energy saving measures? Have the targets been met? Or has the consumption decreased because energy sources were substituted?
- Where can I find appropriate benchmarks?
  - Ask colleagues for data from a particular sector.
  - Ask plant manufacturers for data.
  - Search in literature (research, magazines);
  - Carry out own calculations.

Task 18: Calculate EnPI energy consumption and costs

Table 6: EnPI energy consumption

Energy Performance Indicators (EnPI)												Date: 12 juni 2018	
Company: Fresh and Tasty			Author: Jane Browne							Version: 1			
	Unit	Quantity						Costs [US$]					
Energy		2014	2015	2016	2017	2018	2019	2014	2015	2016	2017	2018	2019
Electricity	kWh	204,765	203,498	206,751	207,500			16,381	18,315	22,743	24,900		
Petrol	kWh	7,965	9,735	8,850	11,063			5,600	6,800	8,100	9,500		
Diesel	kWh	79,200	84,150	89,100	94,050			720	990	1,000	1,375		
EnPI Energy consumption	[kWh/ton]	**1,460**	**1,487**	**1,385**	**1,353**								
EnPI Energy costs	[US$/ton]							**114**	**131**	**145**	**155**		

Task 21: Identify Energy guzzlers: A. Cold storage room

So, Jane starts with the cold storage room. It has 40m² and cold air is supplied by a central AC-unit with 15kW electrical power. The cold room temperature setting is 2 °C. The AC unit is fairly new as it was installed only two years ago.

Jane has a good impression of the efficiency of the AC unit- however she thinks that the temperature setting of 2 °C might be unnecessary low. Usually, the optimum storage temperature for their kind of beans is 7 °C. Since she has learned that an increase in cooling temperature of only 1 °C gives an electrical energy saving of 4%, she wants to increase the set point temperature from 2 °C to 7 °C.

In total, that would give an energy saving of 5 °C x 4% = 20% of the consumption of the AC unit.

As Jane has found out earlier, the consumption of the AC unit is 91,980 kWh per year. 20% of it would be an energy saving of 18,396 kWh per year. With an electricity tariff of $0.12/kWh, this would lead to an energy cost saving of US$ 2,207 per year- for free, because no investment is needed for that!

Task 22: Identify Energy guzzlers: B. Lighting

Jane is so pleased that she found her first energy saving that she continues with the 'investigation' of the other energy guzzlers. Next, she looks at the lighting system of the packing storage area, about 300m². The area is lit by 20 high-pressure-mercury lamps of 450W each. Jane knows that the lamps are old and she suspects they have been in use for least 20 years. The light they give is not suitable anymore for a working area, they have become quite dim. Jane would like to go for the latest, energy saving LED-technology. However, she is not sure whether such an investment will pay off in time.

The installed power of the lamps is 20 lamps x 450 W = 9,000 W or 9 kW. The yearly running time is 3,500 hours. Thus, the annual electricity consumption is 9 kW x 3,500 h = 31,500 kWh. With the electricity tariff of $0.12/kWh, the yearly energy costs are US$ 3,780.

Jane now knows that she can replace the old lamps with LEDs. One LED lamp costs US$ 350. Usually, a 450W lamp can be replaced by a 150W LED-lamp to have the same amount of light in the working area as before, even at a much better brightness. Thus, the LED lamps would have only 20 lamps X 150W= 3,000 W or 3 kW power and consume only 3 kW x 3,500 h = 10,500 kWh per year. Their energy costs would be US$ 1,260 which would be a cost saving of US$ 2,520 per year.

Table 7: Total power and energy costs old versus new lamps

	Qty	Power (W)	Total power (kW)	Running time (hrs)	Energy (kWh)	Tariff ($)	Electr. costs ($)
Old lamps	20	450	9	3,500	31,500	0.12	3,780
New lamps	20	150	3	3,500	10,500	0.12	1,260
						Saving	2,520

However, energy is only one cost factor in lighting. Jane has observed that she needs to replace four of the old lamps a year due to age. One lamp costs US$80. With LED, the lifetime is more than double than that of the old lamps. The yearly replacement costs of US$ 320 including the electrical costs (see Table 7) of US$ 3,780 are in total US$ 4,100 for the old lamps- compared to US$1,260 for LED-lamps.

Table 8: Maintenance old versus new lamps

	Lifetime	Price ($)	Replacement	Maint. cost ($) p.a.
Old lamps	3	80	4 per year	320
New lamps	10	350	none in the first 10 years	0
			Saving	320

Table 9: Total Cost Saving

	Total energy (kWh)	Total costs ($)
Old lamps		
New lamps		
Savings		
Percentage		

Altogether, the yearly cost saving would be US$ 2,840. This a reduction of 70%. Jane can calculate the simple payback time. As already mentioned the cost for one LED lamp is $350. The cost of installing the 20 LED lamps is US$500. The total investment which includes the installation cost is US$ 7,500. When she divides the total investment by the yearly cost savings, she can calculate a payback time. **Please calculate the payback time in the table below:**

Table 10: Payback time

	Qty	Price ($)	Installation ($)	Investment ($)
New lamps	20	350	500	7,500
			Divided by savings ($)	2,840
			Payback time (yrs)	2.6

Which conclusion can Jane draw from calculating the payback time?

In under three years, the investment would payback and the company would save money. Considering a lifetime of the LED lamps of 10 years in this case, this is an investment that is worthwhile to do.

Task 23: Identify Energy guzzlers: C. Blast freezer

Although the blast freezers in use are quite modern, Jane anyway wants to have a closer look at how efficient they are. What would you consider in terms of energy efficiency of Jane's blast freezers?

- The right size for the job: An easy way to reduce energy use in blast freezing is to have a unit designed to freeze just the amount of food needed. If you are producing low volumes of food a small blast freezer will be more efficient than a large oversized one.
- Before you begin: Ensure that the blast freezer is switched on and is at the correct temperature (3 °C for chilling / -18 °C for freezing) before product is loaded, otherwise the refrigeration system will be overworked. As well as being less efficient to run there's the risk that the freezing cycle may not complete in time. It is beneficial to let products that have been heated rest to ambient temperature before entering the freezer (if this does not contradict food safety regulations).
- Half loads: When blast freezing less than a full load, space the trays out evenly throughout the cabinet. This will speed up the process and ensure the product is uniformly chilled. If possible, use a product probe to control the cycle, as this will save energy by stopping the cycle as soon as the correct temperature is reached.
- Use a product probe: Using a product probe to control the blast cycle can save energy. To ensure the most accurate temperature readings, position the probe in the middle of the tray on the middle shelf, in the densest part of the product.
- Air distribution: Having even, all round air flow not only ensures uniform freezing and minimises the risk of damaging the food but also reduces energy use.
- Self-diagnostics: With any unit maintenance is key to ensuring your product runs efficiently for the life of the unit. Blast freezers are available with self-diagnostics, which mean service engineers can quickly find a fault and correct it. Maintenance reminders such as condenser cleaning lights are also invaluable in keeping your refrigeration running smoothly.
- Keep it closed: Once the blast cycle has started, do not open the door, for example to add more trays of product. The food already in the unit will be subjected to warm air, while the food that is added won't get the full blast cycle. This not only reduces the efficiency of the unit but, food safety will be compromised.

- Don’t cover food: Don’t cover food in trays in the blast freezer, it will compromise the efficiency of the blast cycle. Modern blast chillers and freezers have special airflow designs which protect even delicate food, so there is no need to cover it.

High performance insulation: increased thermal efficiency can be achieved with improved insulation. By maintaining a constant temperature more easily, and reducing heat ingress the refrigeration unit will have to work less, thereby reducing its energy use.

Task 24: Calculate the financial gain or loss at the end of year Five

What would be the financial gain or loss at the end of year Five?

In five years, the situation would look like this:

- Saving from fuel and maintenance: 5 years * $816 = +$4,080
- One-time salvage from selling the old truck: +$1,000
- Leasing fee to the cooperative: 5 years * 12 months * $50 = -$3,000
- Result at the end of five years: +$2,080

Jane makes a profit by leasing the cooperative truck. Another advantage is that she is no longer dependent on the increase in fuel prices, at least for the next five years.

Task 25: Advise Jane in terms of buying a new tractor

In terms of buying a new tractor, what would you advise to Jane?

Below some additional guiding questions:

- **Which steps would you take to come to a decision?**
- **What are the advantages of a new tractor?**
- **What about CO_2-emission?**

There are two ways in terms of buying a new tractor:

- the 'old' way would be to go to the dealer and ask for a new, bigger tractor.
- the 'energy-sensitive' way is to make a procurement-checklist considering several factors:
  1. Fuel efficiency of different tractors
  2. Emissions of the available fuel types
  3. Costs and availability of fuel types
  4. Maximum load of the tractor
  5. Maintenance and spare parts availability and costs

The fuel efficiency is 19.91 litres/hour at an average power of 77 HP[13]. A new tractor of same size would have a fuel efficiency of about 14 litres per hour[14]. Thus, a new tractor could be 30% more fuel efficient. Also, today's tractors can lift much heavier loads than their older brothers due to advanced hydraulic mechanics. Also, new trucks have emission reduction technology like SCR[15] on board, which significantly reduce harmful CO_2 and other emissions.

An additional option would be to go for another fuel- instead of using diesel, Jane could look for an LPG-driven tractor. LPG- which is natural gas- has the advantage of producing fewer CO_2-emissions and, usually, being less expensive than diesel fuel. However, the fuel efficiency is not as good as diesel.

This is a good example for "energy-sensitive procurement"; you agree right?

Task 26: Recommend a renewable energy source

Which renewable energy source would you recommend to Jane?

Solar electricity

Task 27: Explain what the benefits of Solar electricity are.

Could you inform Jane about the benefits of solar electricity?

- It's a 'green' technology: no emissions, no fuel needed, no noise, no fume
- The sun does not send a bill for its energy delivery- it comes free with the sunlight
- Because there are no moving parts like in a generator, maintenance and operation of the solar system is almost free of cost (and trouble)
- It makes the business a little more independent from utilities – it could provide electricity during the power shortages
- It is particularly independent from inflation that causes increase in utility prices for electricity and fuel
- Solar energy is particularly successful in places where there are long sunshine hours and plenty of space – a farm is an ideal spot for that
- Solar energy can be used for a variety of applications in a farming business: providing electricity, solar water pumping instead of using diesel-pumps, solar drying of fruits, nuts etc., solar refrigeration, solar heating and much more.

Since the prices for solar equipment have fallen drastically in recent years, this is just another pro-argument for going solar.

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[13] Because the tractor seldomly works at maximum or minim power.

[14] See www.waterandenergyprogress.org

[15] Selective catalytic reduction technology.

Task 28: Demand cold storage room

As we know from Task 14. Calculate consumption in kWh/Year including share of Total, Energy use and input

Table 4, the demand for the cold storage room is 91,980 kWh per year. However, through the energy audit, Jane has already reduced this demand by increasing the setpoint temperature. Thus, the required demand comes down to 72,984 kWh.

Task 29: Estimate the solar system properties

Table 11: Estimating a solar electrical system

Step	Data	Calculation
1	Identify annual kWh to be powered by the solar system	91,980 kWh
2	Subtract kWh reduced by implementing energy efficiency measures at the equipment	91,980kWh – 18,396kWh = 72,984 kWh
3	Find solar radiation at the location	For Paramaribo, Suriname it is 1,600 kWhy/kW
4	Calculate solar system power by dividing demand by solar radiation	Power = 72,984 kWh/1,600 kWh/kW = 45,6 kW
5	Multiply by 1.2 to cover system inefficiencies	45,6 kWh X 1.2 = 54,7 kW
6	Select solar panels and note the panel size	The expert selected 250W panels
7	Divide by the kW size of each solar panel	54,700W/ 250W = 219 panels needed
8	Calculate the needed space to install the solar panels	Approximate 10 m^2 for every kW; 54,7 kW * 10 m^2 = 547 m^2 area needed

Task 30: Estimate the system cost

Table 13: System cost estimation

Step	Data	Calculation
1	Estimate the needed investment	From table above, a 55kW system with batteries would cost US$3,200 per kW = $175,161
2	If there is any grant available, subtract it	0
3	Calculate the energy cost saving	The solar system supplies 72,984 kWh per year; the electricity tariff is $0.12 per kWh; the energy cost saving is therefore = $8,758 per year
4	Are there any other cost savings, e.g. by production optimisation etc.?	The solar system will provide electricity when the grid power is unavailable; thus, the production loss of $20,000 per year will be avoided
5	Calculate the payback time	$175,161/ ($20,000+$8,758) = 6.1 years

The simple payback time of the system would be 6.1 years. Since solar panels have a warranty time of at least 25 years, this is a good investment. Depending on the increase of electricity and fuel prices, the payback time might even be much less.

Task 31: Develop an energy action plan

Table 14: Energy action plan

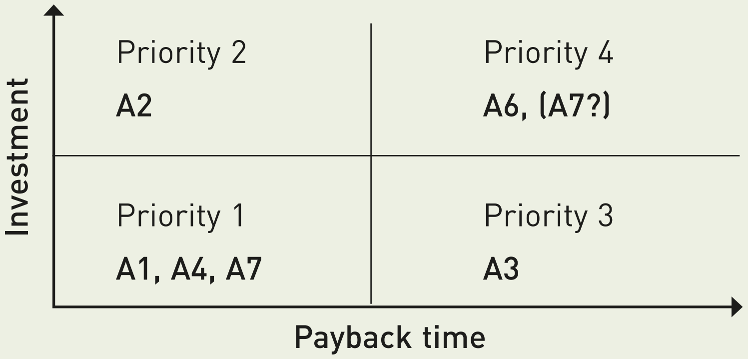
Energy Action Plan						Date: 12 June 2018			
Company: Fresh and Tasty		**Author: Jane Browne**				**Version: 1**			
						Savings			
Topic	Action	Responsible	Deadline	Investment (US$)	Status	ENERGY (kWh)	CO$_2$ (tons)	PROFIT (US$)	Payback [years]
Refrigeration	Increase the set point temperature from 2 °C to 7 °C in the cold room.	Jane	May 2017	0	100%	18,396	10.4	2,207	0.0
Lighting	Change 20 old metal-halide-lamps to LED lamps.	Jane's husband	Oct 2017	7,000	75%	21,000	11.9	2,840	2.5

Ventilation	Retrofit the two 7.5kW-fan motors with variable speed drive (VSD)	Jane	Dec 2017	3,000	50%	15,000	8.5	600	5.0
Transport	Investigate if the bean farmer cooperative can provide one new delivery truck for all our small farms so that we can sell our reefer truck and save the fuel	Jane’s father	1 Feb. 2018	0	0%	4,000	2.3	316	0.0
Transport	Our tractor is almost 20 years old and too small for expansion – request an offer from ‘Brunos Tractor Sales & Repair’ for a new, bigger tractor (maybe it has less fuel consumption?!)	Jane’s father	15 Feb. 2018	cannot say yet	0%	??		?? If any?	?
Renewable energy	‘Smith Solar Works’ made us a proposal for using a 55kW solar PV system to power the cold storage room- we can reduce our production loss!	Jane	30 March 2018	175,161	50%	no saving	41,2	28,758	6,1
Awareness	There are these nice stickers available for download which say ‘Lights out’ and ‘Keep doors closed’ and other things to save energy- we should put them for all staff to remember to be energy-conscious!	Jane	1 Jan. 2018	50	0%	2,000	1,1	200	0,3
	Total			185,211		60,396	75	34,921	

Task 32: List the activities per priority area

Fill in for Jane which of the following Activities (A1 to A7) fits in each priority areas

- A1: Increase the set point temperature from 2 °C to 7 °C in the cold room.
- A2: Change 20 old metal-halide-lamps to LED lamps.
- A3: Retrofit the two 7.5kW-fan motors with variable speed drive (VSD)
- A4: Investigate if the bean farmer cooperative can provide one new delivery truck for all our small farms so that we can sell our reefer truck and save the fuel
- A5: Our tractor is almost 20 years old and too small for expansion- request an offer from “Brunos Tractor Sales & Repair” for a new, bigger tractor (maybe it has less fuel consumption?!)
- A6: “Smith Solar Works” made us a proposal for using a 55kW solar PV system to power the cold storage room- we can reduce our production loss!
- A7: There are these nice stickers available for download which say “Lights out” and “Keep doors closed” and other things to save energy- we should put them for all staff to remember to be energy-conscious!



Which priority area should Jane choose?

Priority area 1

Task 33: Explain what energy objectives are

What are energy objectives?

Energy objectives are describing an overall aim but should be quantified and time scaled. Energy objectives are likely to arise from the energy action plan but might also originate from other sources. The objectives should be focused on priority areas for reducing energy consumption and improving energy efficiency.

Task 34: Explain what monitoring means

What does monitoring mean?

Monitoring means, for example checking if the energy consumption is reducing as planned, but also if the means are available for achieving this goal. It also means regular checks on the operations and energy uses for efficiency. More intensive energy operations should be monitored more regularly simply because more is at stake. Monitoring energy use is vital because "only what is measured can be managed".

Task 35: Calculate the total energy savings and costs including the percentage compared to 2017

These measures alone will generate how many kWh in energy savings per year? 56,396 kWh and in percentage compared to 2017? 18%

These measures alone will generate how many kWh in cost savings per year? US$ 34,605 and in percentage compared to 2017? 97%

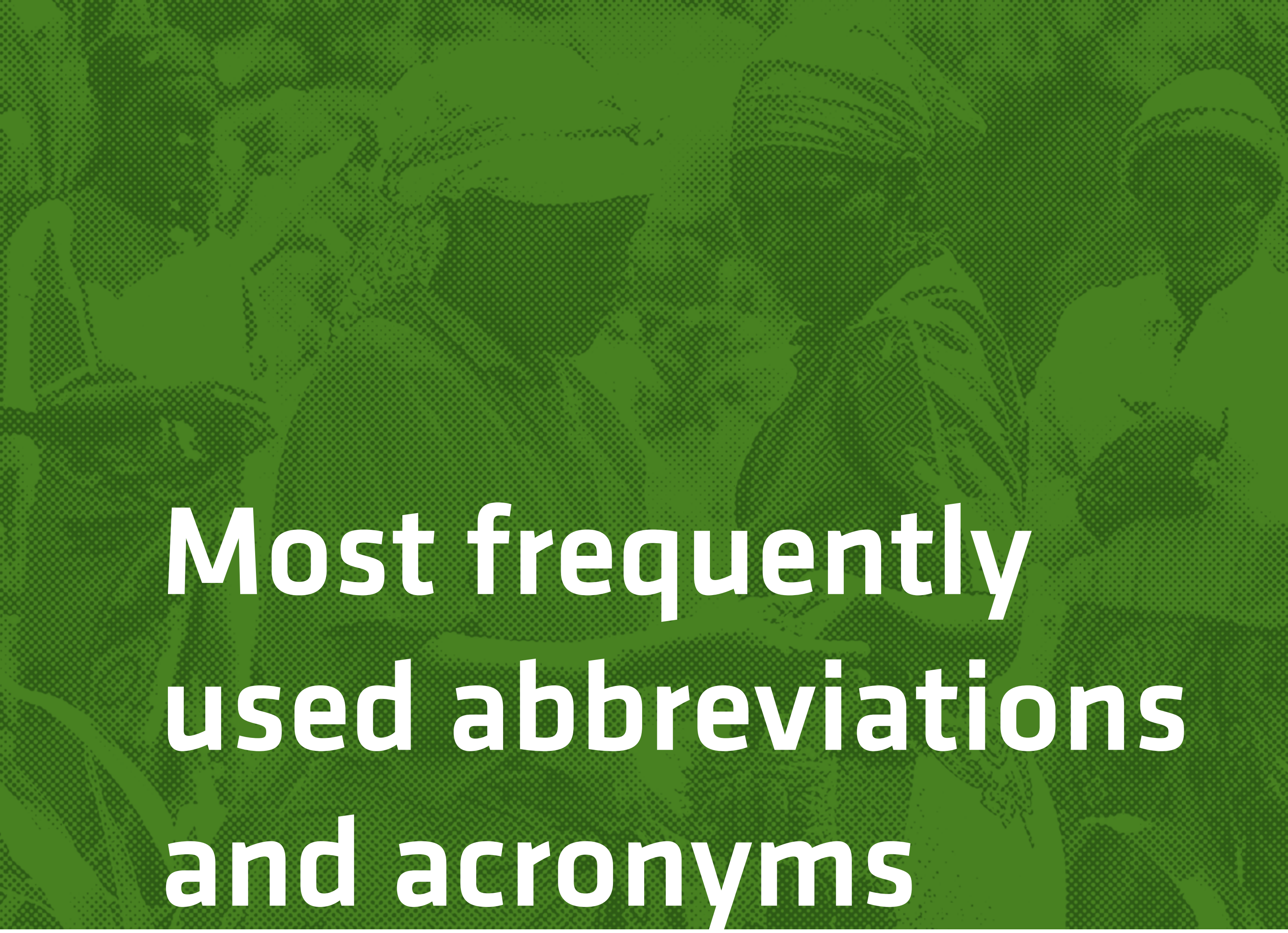
Task 36: Calculate reduction energy consumption and costs

Table 15: EnPI objectives

		2014	2015	2016	2017	2018	2019	2020
EnPI Energy consumption	[kWh/ ton]	1460	1487	1385	1353	1353	1217	1150
Reduction to baseline year 2017	%					0	10	15
EnPI Energy costs	[US$/ ton]	114	131	145	155	155	124	93
Reduction to baseline year 2017	%					0	20	40
Production quantity	tons	200	200	220	231	231	240	240

So the energy objectives of the Fresh and Tasty Company are as follows:

1. Reduce specific energy consumption in kWh per ton by 15% until 2020 (from 2017)
2. Reduce specific energy costs in US$ per ton by 40% until 2020 (from 2017)



Most frequently used abbreviations and acronyms

MOST FREQUENTLY USED ABBREVIATIONS AND ACRONYMS

AC	Air Conditioner
ACP	African, Caribbean and Pacific
AFD	Agence Francaise de Development
AHU	Air Handling Units
AKST	Agricultural Knowledge, Science, and Technology
AREI	Africa Renewable Energy Initiative
BCA	Benefit Costs Analysis
BIO	Biological
BTU	British Thermal Unit
CAPEX	Capital Expenditure
CAPP	Central Africa Power Pool
CARICOM	Caribbean Community and Common Market
CBA	Cost-Benefit Analysis
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture Storage
CCSA	Caribbean Climate Smart Agriculture
CHP	Combined Heat and Power
CNSC	Cashew Nut Shell Charcoal
CNSL	Cashew Nut Shell Liquid
CO_2	Carbon Dioxide
CO_2-eq	Carbon Dioxide Equivalent
CO_2-eq	Carbon Dioxide Equivalent
COLEACP	Europe-Africa-Caribbean-Pacific Liaison Committee
CSA	Climate Smart Agriculture
CSP	Concentrated Solar Power

DC	Direct Current
DOE-2	A widely used and accepted freeware building energy analysis program that can predict the energy use and cost for all types of buildings.
DRC or DR Congo	Democratic Republic of Congo
DTP	Dynamic Tidal Power
EA	Energy Audit
EAPP	Eastern Africa Power Pool
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community of West African States
EE	Energy Efficiency
EEM	Energy Efficiency Measures
EMOs	Energy Management Opportunities
EnMS	Energy Management Systems
EnPI	Energy Performance Indicators
EPA	Environmental Protection Agency
eQUEST	A sophisticated, yet easy to use, freeware building energy use analysis tool that provides professional-level results with an affordable level of effort.
EU	European Union
f/s	Feet per Second
FAO	Food and Agriculture Organization
GCA	The Grenada Cocoa Association
GDP	Gross Domestic Product
GEF small grant programme	Global Environment Facility Small Grants Programme
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft Für Internationale Zusammenarbeit GmbH

GJ	Gigajoule
GmbH	Gesellschaft mit Beschränkter Haftung
GPS	Global Positioning Systems
GTZ	*Deutsche Gesellschaft für Technische Zusammenarbeit*
GW	Gigawatt
h	Hours
HP	Horse power
IAASTD	The International Assessment of Agricultural Science and Technology for Development
ICS	Integral Collector Storage
ICT or ICTs	Information and Communication Technologies
IEA	International Energy Agency
IEC Guide	International Electrotechnical Commission Guide
IFOAM	International Federation of Organic Agriculture Movements
IGSHPA	International Ground Source Heat Pump Association
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
ISO	International Standard Organization
ISV	Institute of Veterinary Services
IT	Information Technology
J	Joules
kCal	Kilo Calorie
kg	Kilograms
kJ	Kilojoule
km	Kilometres
km/h	Kilometres per Hours

kVA	Kilovolt-ampere
kW	Kilowatt
kWh	Kilowatt Hour
l	Litre
LCA	Life Cycle Assessments
LCCA	Life Cycle Cost Assessment
LCO or LCOE	Levelised Cost of Energy
LED	Light-emitting Diode
LM	Lumen
LPG	Liquefied Petroleum Gas
m	Metre
m/s	Metre per second
m^2	Square Metre
MB	Mega Bite
MFP	Multi-function Platform
MJ	Megajoules
MOOC	Massive Open Online Course
MW	Megawatt
MWh	Megawatt-hour
NGO or NGO’s	Non-Governmental Organizations
North-REP	North Pacific ACP Renewable Energy and Energy Efficient Project
NPV	Net Present Value
O & M Schedule	Operations and Maintenance Schedule
^oC	Degrees Celsius
OCGT	Open Cycle Gas Turbine
OECD	The Organisation for Economic Co-operation and Development

OPEX	Operating Expenditure
PAEGC	Powering Agriculture: An Energy Grand Challenge for Development
PDCA	Plan Do Check Act
PDF	Portable Document Format
PESTLE	Political, Economic, Social, Technological, Legal, and Environmental
PIDS	Pacific Island Developing States
PSIDS	Pacific Small Island Developing States
PV	Photovoltaics
R&D funding	Research and Development funding
RCN	Raw Cashew Nuts
RE	Renewable Energy
RES	Renewable Energy Sources
ROI	Return on Investment
s	Second
SADC	Southern African Development Community
SANGA	Strengthening of Livestock Services of Angola
SAPP	Southern African Power Pool
SCM	Standard Cubic Metres
SD	Sustainable Development
SDG 7	Sustainable Development Goal 7
SE	Sustainable Energy
SE4ALL	Sustainable Energy for All
SEU	Significant Energy Uses
SIDS	Small Island Developing States
SMART	Specific, Measurable, Achievable, Realistic and Time-Bound
SME	Small to Medium Enterprises
SMEs	Small to Medium Enterprises

SPT	Simple Payback Time
SWOT	Strengths, Weaknesses, Opportunities, Threats
TEMP	Temperature
ToR	Terms of Reference
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
US$	United States Dollar
USA	United States of America
USAid	United States Agency for International Development
USD	United States Dollar
VSD	Variable Speed Drive
W	Watt
WAPP	West African Power Pool
WEF	Water-Energy-Food
YR	Year

Glossary

GLOSSARY

Actor	Participant in an action or process
Adaptation as it relates to climate change	Is a response to global warming and climate change, that seeks to reduce the vulnerability of social and biological systems to relatively sudden change and thus offset the effects of global warming. Even if emissions are stabilized relatively soon, global warming and its effects should last many years, and adaptation would be necessary to the resulting changes in climate. Adaptation is especially important in developing countries since those countries are predicted to bear the brunt of the effects of global warming. That is, the capacity and potential for humans to adapt (called adaptive capacity) is unevenly distributed across different regions and populations, and developing countries generally have less capacity to adapt (Schneider *et al.*, 2007). Furthermore, the degree of adaptation correlates to the situational focus on environmental issues. Therefore, adaptation requires the situational assessment of sensitivity and vulnerability to environmental impacts. Adaptive capacity is closely linked to social and economic development (IPCC, 2007)
Agro-food chain	When the term is used in agro-economic studies it refers to the combination of agents and activities that, with regards to a product or a group of products of agricultural origin, allow the production of their raw material, their transfer in time and space, and their transformation if needed, making it possible to adjust to consumers' needs and preferences.
Anthropogenic as it relates to climate change	Refers to the production of greenhouse gases emitted by human activity. By examining the polar ice cores, scientists are convinced that human activity has increased the proportion of greenhouse gases in the atmosphere, which has occurred at an alarming rate over the past few hundred years.
Bioenergy	It consists of livestock residues; short-rotation forest plantations; energy crops; the organic component of municipal solid waste; and other organic waste streams. Through a variety of processes, these feedstocks can be directly used to produce electricity or heat, or can be used to create gaseous, liquid, or solid fuels. The range of bioenergy technologies is broad and the technical maturity varies substantially. Recent developments demonstrate that solid biomass and liquid biofuels are increasingly being traded at the international level.
Carbon capture and storage	The process of trapping carbon dioxide produced by burning fossil fuels or any other chemical or biological process and storing it in such a way that it is unable to affect the atmosphere.

Carbon pricing	The method favored by many economists for reducing global-warming emissions — charges those who emit **carbon** dioxide (CO_2) for their emissions. That charge, called a **carbon price**, is the amount that must be paid for the right to emit one tonne of CO_2 into the atmosphere.
Carbon sinks	A forest, ocean, or other natural environment viewed in terms of its ability to absorb carbon dioxide from the atmosphere.
Climate change	A change in global or regional climate patterns, in particular a change apparent from the mid to late 20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.
Climate-smart agriculture as defined by FAO	Climate-smart agriculture (CSA) is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. CSA aims to tackle three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible. CSA is an approach for developing agricultural strategies to secure sustainable food security under climate change. CSA provides the means to help stakeholders from local to national and international levels identify agricultural strategies suitable to their local conditions. CSA is one of the 11 Corporate Areas for Resource Mobilization under the FAO's Strategic Objectives. It is in line with FAO's vision for Sustainable Food and Agriculture and supports FAO's goal to make agriculture, forestry and fisheries more productive and more sustainable".
Co-benefits	Of climate change mitigation as defined in the 4th Assessment Report of the Intergovernmental Panel on Climate Change are the positive **benefits** related to the reduction of greenhouse gases.
Cotonou Agreement	Is a treaty between the European Union and the African, Caribbean and Pacific Group of States ('ACP countries'). It was signed in June 2000 in Cotonou, Benin's largest city, by 78 ACP countries (Cuba did not sign) and the then fifteen Member States of the European Union. It entered into force in 2003 and was subsequently revised in 2005 and 2010.

Direct solar energy	Technologies harness the energy of solar irradiance to produce electricity using photovoltaics (PV) and concentrating solar power (CSP), to produce thermal energy (heating or cooling, either through passive or active means), to meet direct lighting needs and, potentially, to produce fuels that might be used for transport and other purposes. The technology maturity of solar applications ranges from R&D (e.g., fuels produced from solar energy), to relatively mature (e.g., CSP), to mature (e.g., passive and active solar heating, and wafer-based silicon PV). Many but not all of the technologies are modular in nature, allowing their use in both centralized and decentralized energy systems. Solar energy is variable and, to some degree, unpredictable, though the temporal profile of solar energy output in some circumstances correlates relatively well with energy demands. Thermal energy storage offers the option to improve output control for some technologies such as CSP and direct solar heating.
Ecosystem services	The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth. Ecosystem services fall into the following categories: • Provisioning services – the products obtained from ecosystems, including, for example, genetic resources, food and fibre, and fresh water. • Regulating services – the benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases. • Cultural services – the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values. • Supporting services – ecosystem services that are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat (Green Facts).
Energy audit	Is an inspection, survey and analysis of energy flows, for energy conservation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the output(s). In commercial and industrial real estate, an energy audit is the first step in identifying opportunities to reduce energy expense and carbon footprints.

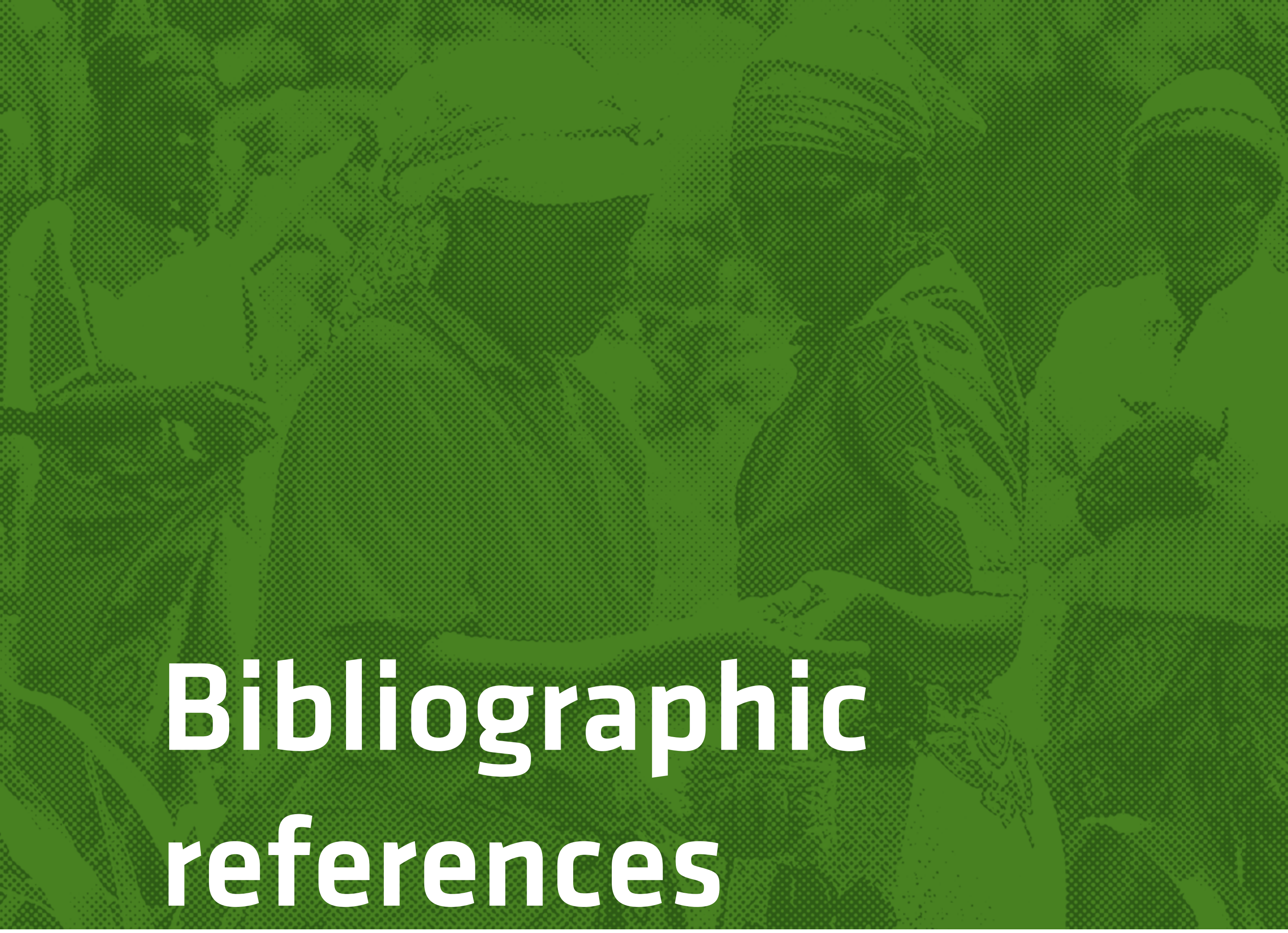
Energy smart food systems	Involve: • relying more on low-carbon energy systems and using energy more efficiently; • strengthening the role of renewable energy within food systems; • providing greater access to modern energy services for development, and at the same time supporting the achievement of national food security and sustainable development goals.
Enteric methane emissions	(According to FAO) Enteric fermentation is a natural part of the digestive process of ruminants where microbes decompose and ferment food present in the digestive tract or rumen. Enteric methane is one by-product of this process and is expelled by the animal through burping. Other by-products of the fermentation process are compounds which are absorbed by the animal to make milk and meat. The amount of enteric methane emission by the animal is directly related to the level of intake, the type and quality of feed, the amount of energy it consumes, size, growth rate, level of production, and environmental temperature. Between 2-12% of a ruminant's energy intake is typically lost through the enteric fermentation process. Enteric methane is a Short-Lived Climate Pollutant (SLCP) and has a half-life of 12 years – in comparison to carbon dioxide, parts of which stay in the atmosphere for many hundreds to thousands of years. Methane traps 84 times more heat than Carbon Dioxide over the first two decades after it is released into the air.
Food security	(According to FAO) is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious **food** that meets their dietary needs and **food** preferences for an active and healthy life.
(Fossil) Fuel switching	Is the substitution of one energy source for another in order to meet requirements for heat, power, and/or electrical generation. Generally, this term refers to the practices of some industries that can substitute between natural gas, electricity, coal, and LPG without modifying their fuel-consuming equipment and that can resume the same level of production following the change.

Geothermal energy	Utilizes the accessible thermal energy from the Earth's interior. Heat is extracted from geothermal reservoirs usingwells or other means. Reservoirs that are naturally sufficiently hot and permeable are called hydrothermal reservoirs, whereas reservoirs that are sufficiently hot but that are improved with hydraulic stimulation are called enhanced geothermal systems (EGS). Once at the surface, fluids of various temperatures can be used to generate electricity or can be used more directly for applications that require thermal energy, including district heating or the use of lower-temperature heat from shallow wells for geothermal heat pumps used in heatingor cooling applications. Hydrothermal power plants and thermal applications of geothermal energy are mature technologies, whereas EGS projects are in the demonstration and pilot phase while also undergoing R&D. When used to generate electricity, geothermal power plants typically offer constant output.
Hydropower	Harnesses the energy of water moving from higher to lower elevations, primarily to generate electricity. Hydropower projects encompass dam projects with reservoirs, run-of-river and in-stream projects and cover a continuum in project scale. This variety gives hydropower the ability to meet large centralized urban needs as well as decentralized rural needs. Hydropower technologies are mature. Hydropower projects exploit a resource that varies temporally. However, the controllable output provided by hydropower facilities that have reservoirs can be used to meet peak electricity demands and help to balance electricity systems that have large amounts of variable RE generation. The operation of hydropower reservoirs often reflects their multiple uses, for example, drinking water, irrigation, flood anddrought control, and navigation, as well as energy supply.
Leapfrog technology	Is the notion that areas which have poorly-developed **technology** or economic bases can move themselves forward rapidly through the adoption of modern systems without going through intermediary steps.
Levelized cost	Of electricity (**LCOE**), also known as **Levelized Energy Cost** (LEC), is the net present value of the unit-**cost** of electricity over the lifetime of a generating asset. It is often taken as a proxy for the average **price** that the generating asset must receive in a market to break even over its lifetime.
Low-carbon	Economy (LCE), **low**-fossil-fuel economy (LFFE), or decarbonised economy is an economy based on **low carbon** power sources that therefore has a minimal output of greenhouse gas (GHG) emissions into the biosphere, but specifically refers to the greenhouse gas **carbon** dioxide.

Mitigation as it relates to climate change	Consists of actions to limit the magnitude or rate of long-term climate change. Climate change mitigation generally involves reductions in human (anthropogenic) emissions of greenhouse gases (GHGs). Mitigation may also be achieved by increasing the capacity of carbon sinks, e.g., through reforestation. Mitigation policies can substantially reduce the risks associated with human-induced global warming
Ocean energy	Derives from the potential, kinetic, thermal and chemical energy of seawater, which can be transformed to provide electricity, thermal energy, or potable water. A wide range of technologies are possible, such as barrages for tidal range, submarine turbines for tidal and ocean currents, heat exchangers for ocean thermal energy conversion, and a variety of devices to harness the energy of waves and salinity gradients. Ocean technologies, with the exception of tidal barrages, are at the demonstration and pilot project phases and many require additional R&D. Some of the technologies have variable energy output profiles with differing levels of predictability (e.g., wave, tidal range and current), while others may be capable of near-constant or even controllable operation (e.g., ocean thermal and salinity gradient.
Primary energy sources	Are embodied in natural resources (e.g. coal, crude oil, natural gas, uranium, and renewable sources). The International Energy Agency (IEA) utilises the physical energy content method for classification, according to which primary energy is defined as energy that has not undergone any anthropogenic conversion. Primary energy is transformed into **secondary energy** by cleaning (natural gas), refinement (crude oil to oil products) or by conversion (into mechanical power, electricity or heat).
Pay-as-you-go	Is a system in which a person or organization pays for the costs of something when they occur rather than before or afterwards.
Resilience as it relates to climate change	Can be generally defined as the capacity for a socio-ecological system to: (1) absorb stresses and maintain function in the face of external stresses imposed upon it by climate change and (2) adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future climate change impacts
Secondary energy	Is delivered at the end-use facilities it is called final energy (e.g. electricity at the wall outlet) that becomes usable energy in supplying services (e.g. light).

Stakeholder	A person such as an employee, customer or citizen who is involved with an organisation, society, etc. and therefore has responsibilities towards it and an interest in its success (source Cambridge Dictionary available at https://dictionary.cambridge.org/dictionary/english/stakeholder
Sustainable development	Has been **defined** in many ways, but the most frequently quoted **definition** is from Our Common Future, also known as the **Brundtland** Report: "**Sustainable development** is **development** that meets the needs of the present without compromising the ability of future generations to meet their own needs".
Sustainable energy	Is energy that is consumed at insignificant rates compared to its supply and with manageable collateral effects, especially environmental effects. Another common definition of sustainable energy is an energy system that serves the needs of the present without compromising the ability of future generations to meet their needs. The organizing principle for sustainability is sustainable development, which includes the four interconnected domains: ecology, economics, politics and culture.
Sustainable energy 4 all	Mission **empowers leaders to broker partnerships and unlock finance to achieve universal access to sustainable energy, as a contribution to a cleaner, just and prosperous world for all.** The initiative was launched by the UN Secretary-General in 2011. It has three interlinked objectives to be achieved by 2030: (i) ensure universal access to modern energy services; (ii) double the global rate of improvement in energy efficiency; and (iii) double the share of renewable energy in the global mix. **Further information is available at** http://www.se4all.org/
Triple wins	A termed used to describe successes in the three sectors of SD i.e., environment, economy and society
Value chain	A value chain in agriculture identifies the set of actors and activities that bring a basic agricultural product from production in the field to final consumption, where at each stage value is added to the product. A value chain can be a vertical linking or a network between various independent business organizations and can involve processing, packaging, storage, transport and distribution. The terms 'value chain' and 'supply chain' are often used interchangeably.
Vulnerability as it relates to climate change	The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Wind energy	Harnesses the kinetic energy of moving air. The primary application of relevance to climate change mitigation is to produce electricity from large wind turbines located on land (onshore) or in sea- or freshwater (offshore). Onshore wind energy technologies are already being manufactured and deployed on a large scale. Offshore wind energy technologies have greater potential for continued technical advancement. Wind electricity is both variable and, to some degree, unpredictable, but experience and detailed studies from many regions have shown that the integration of wind energy generally poses no insurmountable technical barriers.



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Useful Web sites

USEFUL WEB SITES

ACP-EU Energy Facility
energyfacilitymonitoring.eu/
(in both English and French)

African Development Bank Sustainable Energy Fund for Africa
www.afdb.org/en/topics-and-sectors/initiatives-partnerships/sustainable-energy-fund-for-africa/

AREI (Africa RE Initiative)
www.arei.org/
provides reports in both English and French

Caribbean Development Bank Renewable Energy and Energy Efficiency
www.caribank.org/energy ● Le lien ne fonctionne pas

FAO
www.fao.org/energy/home/en/
available in English, French and Spanish

GIZ Renewable Energy, energy efficiency and access to energy services
www.giz.de/en/worldwide/20886.html

Green Climate Fund (Pacific Islands)
www.greenclimate.fund/-/pacific-islands-renewable-energy-investment-program

International Energy Agency
www.iea.org/topics/renewables/

IRENA
www.irena.org/publications

Renewable Energy Caribbean
renewableenergycaribbean.com/tag/project-financing/

Renewable energy world
www.renewableenergyworld.com

Secretariat of the Pacific Regional Environment Program PIGGAREP
www.sprep.org/Pacific-Islands-Greenhouse-Gas-Abatement-through-Renewable-Energy-Project/about-piggarep ● Le lien ne fonctionne pas

SE4ALL
www.se4all.org/sites/default/files/2017_SEforALL_FR4_PolicyPaper.pdf

USAid Energy
www.usaid.gov/what-we-do/economic-growth-and-trade/infrastructure/energy

World Bank Energy
www.worldbank.org/en/topic/energy

www.ecowapp.org

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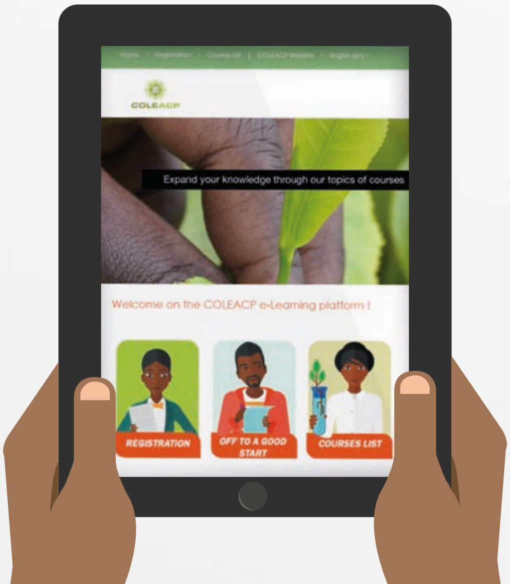

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