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Synergies in increasing access to sustainable energy and developing agriculture in ACP countries

Experiences from EU-supported projects in ACP countries 2007-2019

7 AFFORDABLE AND CLEAN ENERGY

2 ZERO HUNGER

ACP-EU Energy Facility Monitoring

European Commission

DANISH ENERGY MANAGEMENT DEM FOR SUSTAINABLE IMPACT

The ACP-EU Energy Facility (http://energyfacilitymonitoring.eu)

This discussion paper is one in a series of discussion papers based on experiences from the ACP-EU Energy Facility (EF).

The EF was established in 2005 to co-finance projects on increasing access to modern and sustainable energy services for the poor in African, Caribbean and Pacific (ACP) countries, especially in rural and peri-urban areas. 173 project proposals have been granted co-funding from the EU for a total of 0.4 billion euros; 50% of the total project-budgets of 0.8 billion euros.

The projects have been, and are being, implemented in the period 2007-2021 with 90% of projects completed in 2019. The projects cover a wide range of technologies:

Electricity grid-extensions in rural and peri-urban areas, hydro-powered mini-grids, solar and hybrid-solar mini-grids, stand-alone solar solutions for businesses, households and public institutions, portable solar equipment mainly used for lighting, clean energy solutions for cooking such as improved firewood and charcoal cook stoves as well as biogas, biofuels for electricity generation, and capacity development of public institutions in the energy sector.

Among the 173 Energy Facility projects, 29 (17 percent) are directly relevant to agriculture.

Danish Energy Management (DEM) has been granted the contract of providing technical assistance for the monitoring of the EF projects in the period 2011-2019. This discussion paper is based on information and data gathered during this period as well as current research and experience from other development interventions.

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Introduction

This discussion paper tries to raise some of the key considerations on how energy access interacts with agriculture: how energy inputs increase agricultural production?, which energy inputs are most relevant for agriculture products transformation and which are their effects?, and what are the lessons learned from growing energy crops specifically from ACP-EU Energy Facility (EF) Jatropha projects[1]? Finally, it discusses current trends and paths forward concerning the 'energy-agriculture nexus' and tries to describe how the development of photovoltaic (PV) and other renewable energy projects helps creating better products for agriculture.

Essentially, the Food and Agriculture Organization of the United Nations (FAO)[2] considers that 'Insufficient modern energy is available for agriculture and this affects food security' and that 'There is a general lack of rural energy development policies that focus on agriculture'. In this context, there are obvious links between **SDG 2 (zero hunger)**, the core SDG connected with agriculture and **SDG 7 (Affordable and Clean Energy)**.

The energy—agriculture nexus is also key for the realization of other SDGs:

SDG1 (No Poverty): Rural people make up 70% the world's extreme poor. So, agriculture, with energy support, for example through water pumping for irrigation, can contribute more to reducing poverty than any other sector.

SDG6 (Clean Water and Sanitation): By 2030, the global demand for water will have doubled, with agriculture alone requiring more than what can be sustained to feed the world (even before domestic and industrial needs are met). This demand can only be met with the use of modern energy solutions for pumping or water treatment.

SDG8 (Decent Work and Economic Growth): In rural areas, agriculture can be an engine of employment and pro-poor economic growth. Agriculture products transformation on large scale will entail energy inputs for solar drying, grinding, processing, cold storage, etc.

SDG13 (Climate Action): By 2030, agriculture's carbon mitigation potential could reach as much as 7.5% of total global emissions, depending on the price of carbon and adoption of agricultural productivity measures.

[1] Jatropha curcas is a species of flowering plant in the spurge family, Euphorbiaceae, that is native to the American tropics, most likely Mexico and Central America. The seeds contain 27–40% oil that can be processed to produce a high-quality biodiesel fuel, usable in a standard diesel engine. Edible (non-toxic) provenances can be used for animal feed and food.

[2] Environment and Natural Resources Working Paper No. 4. The Energy and Agriculture Nexus

Background

A wide range of modern and traditional energy forms are used directly on the farm, e.g. as tractor or machinery fuel, and in water pumping, irrigation and crop drying. Energy inputs also play a role indirectly for fertilizers and pesticides. In addition, post-harvest processing in food production, packaging, storage, transport and cooking need various energy inputs as well. Energy for agricultural practices in many developing countries continues to be based on human and animal energy to a large extent, and on traditional wood-fuels. Empirical evidence suggests that the potential gains in agricultural productivity through the deployment of modern energy services are far from being realized in developing countries. For economy and sustainability obvious reasons, reliance on renewable forms of energy may help increasing energy inputs in the agriculture value chains in developing countries. On the other hand, experience from the EF and other programs suggests that the provision of locally sourced energy through the exploitation of energy crops in modern biomass systems could stimulate rural economic development and offer at the same time a potential for improved energy supply. Agriculture can also make a major contribution to climate change mitigation by CO2 substitution of fossil fuels since biomass is generally considered a carbon-neutral energy source over a short time under the condition that the source is renewable as it is the case with agricultural waste. Biomass offers the prospect of fulfilling a dual role by combining sustainable development in rural areas and climate change mitigation.

The below table illustrates the various interactions between renewable energy and agricultural practice at different levels of the value chain.

Table 1: Energy Inputs in agricultural value chains

Primary Production	Post-Harvest and Storage	Transport and Distribution	Processing	Retail, Preparation and Cooking
• Solar, wind-based water pumping • Biofuels for tractors and on-farm machinery • Solar-based desalination, heating and cooling for protected cropping • Biomass residues use for on-site energy generation • Indirect renewable energy inputs for fertilisers	• Solar, geothermal food drying • Solar cooling and refrigeration	• Biofuel use for transportation and distribution • Solar cooling and refrigeration	• Solar, wind, hydro-based milling, threshing • Renewable energy-based electricity and heat applications	• Renewable energy-based water purification • Modern biomass use for cooking applications

Source: Based on FAO, 2011b; Practical Action, 2012

Lessons from the projects supported by the ACP-EU Energy Facility can contribute to the discussion.

29 projects – 17 percent – in the Energy facility have specifically addressed agricultural issues. Out of those, 10 have addressed water pumping and irrigation issues, 8 have addressed biogas and fertilizers from biogas production, 4 have addressed solar drying, 2 have addressed cold storage, 11 have addressed mechanical processing and 16 have addressed energy crops. Several projects address several aspects.

On this basis, this paper proposes analyzes and developments on three levels: (i) the energy inputs for an increased agricultural production, (ii) the energy inputs for the transformation of farming products and (iii) the question of growing energy crops. It tries to draw lessons learned from these projects, including on the long-term management and payment of the energy inputs in the agriculture value chain, and on the experience with Jatropha Curcas cultivation and its use as an energy crop.

Energy inputs for increased agricultural production

The importance of the energy-food nexus cannot be neglected: The agri-food supply chain accounts for 30% of the world's energy consumption and is the largest consumer of water resources, accounting for approximately 70% of all freshwater use.

The energy–food nexus relates mainly to energy use within the food supply chain. Depending on the extent of mechanisation, agricultural production consumes energy directly in the form of fuels for land preparation and tillage, crop and pasture management, and transportation or electricity supply, and indirectly through the use of energy-intensive inputs, such as fertilizers and pesticides, or energy for manufacturing agricultural machinery. Energy is also needed during processing, distribution, storage, retail and preparation of food products. This makes food security particularly sensitive to the quality and price of energy inputs effect on the price of food.

Water pumping and irrigation

Agriculture is the world's largest user of water, accounting for over 70% of global freshwater withdrawals (and up to 90% in some countries). Water is also used throughout the agri-food chain, including processing, distribution, retailing and consumption. Not only is water used during the different stages, but it is physically part of the goods being handled and traded.

By 2050, a projected 60% increase in agricultural production, will cause water consumption for irrigation to rise by 11% and withdrawal by 6%, despite accounting for modest gains in water efficiency and crop yields (FAO, 2009). Although a seemingly modest increase, much of it will occur in regions already suffering from water scarcity and witnessing intense competition with other sectors, including manufacturing, electricity production and domestic use. In the face of these competing demands, increasing allocation of water for irrigation will be challenging[3].

Irrigation system at an agricultural field
Photo: Danish Energy Management (DEM)

[3] OECD-FAO, 2012

Irrigation will have to play an important role in increasing food production. Growth in agricultural production to feed a projected human population of over 9 billion in 2050 will come from (i) increasing crop yields, and (ii) expanding arable land area, together with increases in cropping intensities (i.e., by increasing multiple cropping and/or shortening fallow periods). Yields of irrigated crops are well above those of rain-fed ones. To achieve increased production, the expansion of harvested irrigated land area is estimated to rise nearly 12% to 2050, compared to a 9% rise for rain-fed harvested land area[4].

Experiences from the ACP-EU Energy Facility

The 10 EF projects that included water pumping for irrigation are located in different countries across Sub-Saharan Africa using different technologies: Most use solar power to pump water into a water tower which is then distributing water to water points, one project has used wind powered mechanical water pumping and a few projects have included irrigation canals into small hydro powered electrical plants[5].

Water tower
Photo : Programa Comunitário para Acesso a Energias

Common to all of these EF projects, however, is that they have used community-based management arrangements to organize the management of the irrigation systems and some general experiences and lessons learned concerning longer-term management can be drawn.

Two trends mainly affect the longer term management issues and the projects sustainability : one is the lacking of ability to repair installations after damages, for financial or for lack of capacity reasons, the other one is connected with the different degrees of how payment is organized, if it is accepted, and if they have based the tariffs on what it costs to maintain the systems or just what they think people can afford. We have classified those trends under (i) 'Equipment maintenance and technical sustainability' and (ii) 'Payment organization and financial sustainability'.

In general, most project analyses conclude that affordability is not granted or has not been evaluated. In few projects do the beneficiary directly pay for water use. In most cases, they only pay for electricity. When specific water prices are established, there is no indication on how these tariffs have been calculated.

Equipment maintenance and technical sustainability

In the case of the project, *Promoting use of sustainable energy in Wajir District in Kenya*, water pumping techniques were considered difficult to afford for target groups, despite their longer-term cost-benefit. In addition, subsidies will not be available when the project has ended, so the approach is not sustainable. The local structures were kept well informed about the project but did not seem to be directly involved in decision-making. The capacity building of solar technicians has not been undertaken due to non-attendance. This calls into question the sustainability of the solar technology if an insufficient number of technicians are available and able to maintain the systems installed (seems irrelevant)

In the case of the project, *Rural Sustainable Energy Development in Zimbabwe*, the sustainability of the project is very much in question on the basis that systems have gradually begun to fail. PV water pumping equipment has broken down, primarily due

[4] Alexandratos and Bruinsma, 2012

[5] In Discussion Paper 3, pros and cons of different renewable energy solutions to water pumping utilized in the ACP-EU Energy facility is discussed in more detail.

to poor operation and maintenance. The beneficiaries were not able to maintain the equipment and in the case of one school, the committee in charge had engaged in corruption in replacing a solar water pump, which they paid for but was never fixed, and it is therefore not working.

Payments organization and financial sustainability

In the project, *Support to Efficient Utilization of Alternative Energy Sources to Improve the Livelihood of Pastoral and Agro pastoral Communities in Southern Ethiopia*, an evaluation concludes that "Infrastructure such as water supply points is financially self-sustaining" is an exception and further details are unfortunately not provided.

In the project, *Renewable energy for local development in Guinea-Bissau*, the concept involved users paying for usage to cover future maintenance of the water system. During the project, this has been an issue for debate since there was little understanding locally for the need to pay for costs that have not yet materialized and it remains unclear if this issue has been resolved. It is reported that so far communities have been able to pay for repairs.

Water tower
Photo : Programa Comunitário para Acesso a Energias

The project exit strategy proposed the establishment of a non-for-profit association which would promote agricultural and commercial and non-commercial activities to support small scale farmers to increase animal and vegetal production ensuring food security and monetary incomes. Farmers could sell their yield at a fair price or process them through the Production Centres established by the project with a 15% fee. Expected profits would be used for the extension of the service, improve conditions and services and to include new farmers in the system. The trading system itself would be able to approach the market to the farmers and approach other products to them. The strategy is currently being implemented and it is too early to tell the longer-term sustainability of it.

Provision of modern, affordable and sustainable energy services to rural poor communities in West African countries from Jatropha curcas oil: As concerns the Ghana leg of the project, the financial sustainability has been considered uncertain since the project had not performed any cost analysis and there was no clarity on how the Jatropha chain would be set up. There were no estimates of the costs of maintaining the solar system installed by the project, and it was impossible to determine how much water was needed to be sold in order to guarantee that enough funds would be available for routine and emergency maintenance (but not for major repairs and replacement of equipment). Beneficiaries were only partially involved in the implementation and had not developed a strong sense of ownership yet.

In the *Somali Energy Transformation (SET) Project*, farms were assisted to acquire PV driven water pumps to replace those driven by petrol engines. Those surveyed were very happy with the installations and reported significant reductions in the use of petrol for pumping, with reductions of up to 180 liters per month. This excludes savings in other operations and maintenance costs for petrol pumps.

They also reported less downtime, that they could put more acreage under irrigation and experiment with new crops that requires more water, that they could supply the neighboring community with water, especially during drought. The users expressed satisfaction with the reliability of the PV pumps (so far) as well as its low maintenance requirements. However, their main concern was the cost of the systems in case they needed to replace them or buy new ones for expansion. While they could

Solar water pumping system
Photo: DEM

see the benefit, they were not able to conceptualize how to use this benefit to expand the use of similar solar facilities to the rest of their land.

Finally, some community-based projects are coming up with solutions, but it will take more time to know if they are effective. In this context, not much has been said on the relevance of the community-based approaches used in most of the relevant projects to organize the management of the irrigation systems, except in one case: the community-based approach does not seem to have been very successful in the project *Rural Sustainable Energy Development in Zimbabwe*.

More generally, there is clearly a lack of understanding and capacity to manage community-based schemes. There are no resolution mechanisms that will allow the communities to resolve the conflicts and issues that they have. As the project final evaluation report rightly mentions, "Where there are multiple water users, there is need to install agreed water use control devices over and above strengthening the capacity of existing water management committees". There would certainly be an interest in further analysing this aspect in the future. Based on the general experience of the Energy Facility, it is likely that public extension services are playing a key role[6].

Use of fertilizer from biogas digesters

Biogas digesters are fed with agricultural waste (often cow dung) to feed bacteria cultures that produce biogas. The biogas is used for cooking with positive impact on household health also saving time previously used for wood collection through the substitution of wood by biogas and reducing pressure on forest resources. In addition, slurry from the digester can be turned into fertilizer through simple composting processes. Turning the residue into a byproduct is an important advantage of biogas production.

Water tower
Photo : Programa Comunitário para Acesso a Energias

[6] See also discussion paper 8 in this series that examines experiences with institutional capacity building

A study[7] realized in Mali with an International Fund for Agriculture Development (IFAD) funding has shown that "Results have clearly demonstrated that, whichever the crop, the parcels that have received 10, 8 and 6 tons per hectare of digestate (from the biogas digesters) from cow dung have shown higher output than those using standard manure. This positive effect of the digestate is most probably connected with the nitrogen influx".

Case: Program for the installation and dissemination of biodigesters in rural areas in Senegal

The program offers a striking perspective on the use of fertilizer from biogas digesters.

The objective of the program is to provide rural households of nine Senegalese regions with an energy source, both for cooking and for lighting, as well as agricultural fertilizer to support their activity. This was to be done through the installation of 10,000 biodigesters in the rural and peri-urban zones of the selected regions.

Initially concentrated on the energy dimension of the biodigesters, the program dramatically evolved when the agronomic tests of the produced fertilizers showed much higher economic outputs: the payback period of the digester was of 8 years on the basis of the spared firewood valorization, while it was only six month when adding the sales of organic fertilizer produced by the digester. An individual digester produces only 6 kWh per cubic meter of biogas, but the value of the fertilizer that can be produced from it, can pay 3 times the Senegalese minimum salary.

For this reason, the project changed approach and instead of subsidizing the construction costs of the biodigesters, they offered a guarantee fund for companies willing to invest in biodigesters. The beneficiaries reimburse the companies' investment by selling part of the fertilizer they produce to back to them.

Digesters are an expensive system, normally requiring public support for the financing. However, the project *Program for the installation and dissemination of biodigesters in rural areas in Senegal* decided to cancel the subvention, since the sales of fertilizer from the digesters turned out to be extremely profitable. The bio-digesters models most promoted could be built by local craftsmen (masons).

The economic model includes the access of different actors to credit: individual households (for the construction of a bio-digester and the development of connected income generating activities), companies building the digesters, companies selling the fertilizer (sold to them by households through fertilizer producers' organizations), fertilizer producers' organizations. The fertilizer is finally sold to big fertilizer companies.

Access to credit (by local banks) of the various concerned actors is ensured via a guarantee fund managed by FONGIP *(Fonds de Gestion des Investissements Prioritaires)*, a state organization, ensuring transparency and control of the banks financing the promoters.

One of the specific objectives of this project was to increase the farmers' outputs (mainly vegetables farmers including women) using organic fertilizer coming from the biodigesters. In 2016, 16,640 ha were fertilized with this organic fertilizer. By the time of writing, the project is still ongoing in a process of scaling up activities.

[7] Final Report. Project FED/2014/353-512 Accès à des services énergétiques modernes et durables au Mali : Tests agronomiques menés en partenariat avec l'Institut d'Economie Rurale (IER) à travers le Centre Régional de Recherches Agronomiques de Sotuba (CRRA sur financement du FIDA (Fonds International pour le Développement Agricole).

The rural households using the biodigesters effluent on their cultivations have observed an increase of the outputs of their main cultivations. For the millet, the increase of the average output is 102,46 percent when compared with the five previous years official averages (and 109.11 percent when compared with control household in the neighborhood). For peanuts, the increase is 64.69 percent when compared with the previous year's official statistics, and 105.73 percent when compared with the neighboring households. For maize, the average output is 7667 kg/ha with digestat against 3833 percent without; a 100 percent increase.

The use of bio-digesters also necessitates sufficient manure resource. For example, project *Accès à des services énergétiques modernes et durables au Mali* selected households with a minimum of 15 heads of cattle. So, besides creating a new energy source, biogas can have a very positive impact on agriculture. Sale of fertilizer from bio-digesters can be very profitable, but depend on local conditions, and it is still too early to assess the larger scale potential.

Conclusion

- Water pumping for irrigation is in high demand throughout the ACP-region to boost agricultural production. However, the importance of local capacity in management and maintenance is often not taken into due consideration.

- Sound business plans that enables local communities to collect fees for irrigation and pay for maintenance and spare parts is the missing link in several EF project, however not in all.

- The use of slurry from biogas digestors also offers an interesting potential to boost agricultural production. The impact on crop yields is significant.

- Biogas is extensively used in Asia and in some parts of Latin America, however, in Sub-Saharan Africa it is still a novel technology. Better integration of the use of biogas slurry in local agricultural value chains, for instance through compostation, could be Columbus egg that triggers the uptake of biogas digesters on the sub-continent.

Energy inputs for transformation

Energy access is essential for economic development, thanks to the increase in productivity and quality it allows while moving from manual to mechanized work. According to UNIDO (the United Nations Industrial Development Organization), 'Adequate mechanization is the main engine of productivity and competitiveness in agriculture and agro-industries'[8]. It allows the transition from subsistence farming to commercial farming. Moreover, in places where farming work force includes children and the elderly, proper tools and machinery can help reduce their workload while maintaining agricultural production.

Miller using a machine running on Jatropha oil, as a substitute for diesel fuel
Photo: DEM

In the ACP-EU Energy Facility projects, several projects have applied sustainable energy sources to processing of agricultural products to increase their commercial value.

[8] https://www.unido.org/our-focus/creating-shared-prosperity/agribusiness-and-rural-entrepreneurship-development/agro-machinery-and-rural-engineering

Solar drying

A significant share of total energy inputs is embedded in food losses that occur at the harvest and storage stages. As a result, significant attention is given to renewable energy in developing decentralized processing and storage infrastructure.

Solar energy can be successfully used for dry storage. Compared to other food preservation techniques, food drying can be performed using low-temperature thermal sources and is applicable to many different types of food (including fish, fruits and vegetables). The dried food produced is light weight, is easily stored and transported and has an extended shelf life[9].

Thermal solar drying is a very simple technology that has been applied with success in several EF projects:

In the project *Energies durables dans les régions d'Agadez et de Tillabéri*, Niger the overall objective indicators included the improvement of food security with the production of 10.8 tons of dried products per year (1kg fresh product gives 0.15 kg dried product), the limitation of the hunger gap, then limiting the number of households in vulnerability situation, and creating 40 jobs in food transformation with solar driers. The project final evaluation estimated that the socio-economic impact of the proposed technologies (including the solar drying) had been high in terms of working paid time and in the capacity of the beneficiaries to overcome the (food) vulnerability.

Project *Déployer de nouvelles opportunités de développement socio-économique par l'accès aux énergies durables dans le Plateau Central* in Haiti included the setting-up of four pilot installations for the production of charcoal and the start of solar drying of tropical fruits such as mango. The production of charcoal was based on agriculture waste and residues. In this case, the fruit drying solar oven was successfully used for drying the coal briquettes.

Grinding / processing

Processing of agriculture products can provide a lot of benefits such as (i) enhanced agricultural productivity and increased farm household incomes, (ii) year-round availability of affordable safe and nutritious food, (iii) job creation for rural and urban youth (iv) Production of fortified foods for vulnerable groups in society, (v) establishment of indigenous food standards, (vi)the transformation of large quantities of agricultural "waste" produced in one location into useful products such as animal feed, (vii) the reduction of importation of similar or foreign foods and conserve foreign exchange[10].

Since the processing of agriculture products generally necessitates energy access, the EF is an ideal vehicle to support this activity.

The project *SETUP 'Services Energétiques et Techniques à Usage Productif au Bénin'* facilitates the access to energy services and techniques for a productive use to rural populations. The intervention logic includes the facilitation of access to motorization (via multi-functional platforms) to improve post-harvest productivity. Drying, cereal milling, cold conservation, etc., are covered. On average, transforming capacity was multiplied by 8.8.

More specifically, the very small businesses benefitting from agri-food transforming equipment have seen their production volumes multiplied by 2.5 and their gross margin multiplied, on average, by 2.

The duration of their operations diminished by 42%. Equipment is more efficient: production increased from 6 to 9 liters per hour for the palm tree. As a consequence, transformation costs decreased by 44% to 57% of the initial cost of operations. At the same time, the revenues increased, and painfulness at work diminished.

[9] IRENA. Renewable Energy in the Water, Energy & Food Nexus. January 2015

[10] Institute of Applied Science and Technology of the University of Ghana (https://www.ug.edu.gh/iast/node/5)

In other relevant cases, project reports generally do not provide ratios of production increases but refer to the improvement of the farmers living conditions.

For example, project *Energies durables dans les régions d'Agadez et de Tillabéri*, Niger supported mechanical processing for the milling and granulation of animal feed on the basis of harvest residues. On the basis of a production of 9, 30 kilograms, bags per day, this activity leaves an estimated average revenue of 5142 XOF (7.84 euro) per month per beneficiary, all costs deducted.

Cold storage

According to FAO[11], 'The development of cold chains in sub-Saharan Africa will result mainly in reduced food losses and improved market access, encouraging agricultural production and stable food security'.

The cold chain may also include a part of product transformation. The project *Progrès lait* in Mauritania and Senegal provides the rural breeders / milk producers with solar platforms for, among others, milk conservation and transformation of milk derivatives. Plans are to establish 20 solar dairy factories for the conservation and pasteurization, in order to supply big industrial milk transformation factories. Each platform (a solar dairy factory) should purchase a minimum of 800 liters of milk per day.

As of March 2019, three platforms have been installed: one in Mauritania and two in Senegal (one of them sells milk to a local plant, the other one sells milk locally and transforms milk into yogurt for sales in Dakar. Both platforms also distribute electricity).

Milk pasteurisation
Photo: DEM

The project is still ongoing, so longer term impact is still not known. Lessons concerning socio-economic impact can however be drawn from the pilot phase, where a monitoring of 200 livestock breeders has been run in specific village. With 5 collection circuits, some 150,000 liters were collected, ensuring an average revenue of 30,000 XOF (some 46 euro) per month for each livestock breeder.

Cold storage is seen in almost all electricity access projects in the ACP-EU Energy facility on retail level: with electricity, you can buy a freezer and sell cold drinks, store meats and vegetables either for sale or rent.

[11] Policy brief – Developing the cold chain in the agrifood sector in sub-Saharan Africa

The project *Électrification rurale décentralisée interrégionale en Mauritanie (ERUDI)* built and implemented 79 multi-services platforms including freezers (90 freezers have been installed), providing access to energy services to 52,000 people. Cold service is the most appreciated service, since it allows the storage of meat, fruit and fish and provides fresh drinks. Each platform is estimated to create up to three jobs on average offering different kinds of services using the energy from the solar panels of the platforms.

Freezer to storage cold drinks
Photo: DEM

Conclusion

- Thermal solar drying is a very simple technology that has been applied with success in the Energy Facility. The technology can be produced and maintained by local artisans and the surplus for farmers or village associations is evident.

- Access to energy for mechanical processing of crops requires bigger investments, more technical expertise, and stronger management capacities in order to balance revenue with longer-term costs of replacing parts. However, if access to markets are in place, the investments in processing equipment are highly relevant. Access to markets is the crucial condition for these investments to reap longer-term benefits.

- The uptake of freezers and refrigerators for cold storage of beverages and other retail product is witnessed in most EF-projects. For these small business ventures, the business case is clear for the end users as the revenue stream is based on local demand.

- Larger scale cold storage investments that has a deeper impact on local agricultural value chains has potential as well but requires even bigger investments than processing equipment and if markets cannot be easily accessed financial viability is more uncertain.

Growing energy crops

Biofuels are produced from plants or from agricultural, domestic or industrial waste. Although plants sequester carbon in their roots and surrounding soil, biofuels are not always carbon neutral. For a biofuel project to be carbon-neutral, the total carbon sequestered by the energy crop root system should compensate for all the above-ground emissions related to this project. It has been demonstrated that carbon-neutral or even carbon-negative crops are rather high yielding energy crops.

The two main types of biofuels are bioethanol (an alcohol made by fermentation from sugar or starch crops) and biodiesel produced from oil or fats. In the context of the EF, most energy crop projects used Jatropha Curcas.

Lessons learned with jatropha projects

Jatropha is generally nonedible, and its seeds can contain large quantities of oil (more than 2 tons per ha). This oil can be used in adapted engines or chemically transformed in biodiesel that can substitute diesel in cars, trucks and generators. Jatropha was seen as a 'wonder crop' in the first decade of millennium, in a context of high oil prices and a 'peak oil' threat, but it rapidly disappointed its promoters.

Jatropha fences
Photo: DEM

In Tanzania, a 2013 study[12] concluded that "both domestic production and (certified) exports are too expensive to be able to compete with conventional diesel/rapeseed oil from the EU" and global Jatropha production was still negligible by 2014. At the same time, the Jatropha sector collapsed in Ghana. Experience also was negative in South Africa. Many factors have affected the sector:

- Low global oil prices, during the period, have often made jatropha local oil more expensive than imported fuels.
- Jatropha was initially seen as a wasteland and marginal land crop, which was not true: in fact, Jatropha requires good soils, supply of additional nutrients, and enough regular rainfall. Another factor then appeared: the risks on food security from biofuels cultivated on good soils originally intended for food crops, potentially reducing food security in developing countries. Given the slow-down of a number of projects, this risk is no longer present.
- The yields have often been overestimated, while labour and maintenance costs were underestimated. High transport cost from remote plantations was also a drawback.
- Technical issues also have been mentioned. For example, the high acidity level of jatropha oil may damage engines, therefore, this acidity level must be carefully controlled.

Several EF projects, that were engaged in Jatropha planting, did not escape the rule. Below is an overview of the assessment of strong and weak points in the EF monitoring reports. Despite negative aspects often connected with the underestimation of water needs for cultivation, or low oil prices on the markets, the first project below, *Desarrollo local de la zona fronteriza dominicano-haitiana a través de la reforestación con Jatropha curcas y la producción al nivel comunitario de energía renovable a partir de biomasa vegetal* in Dominican Republic, has shown more positive results in terms of biomass fuel for cooking or by product use for making soap, fertilizers, etc.

[12] Segerstedt and Bobert, 2013

Table 2: Overview of assessments of EF jatropha projects

Projects	Conclusions concerning Jatropha
Desarrollo local de la zona fronteriza dominicano-haitiana a través de la reforestación con Jatropha curcas y la producción al nivel comunitario de energía renovable a partir de biomasa vegetal	Underestimated needs of water for the chosen variety of Jatropha leads to productivity below the threshold in dry years. Deficient feasibility study defined area per owner be-low the real profitability threshold which makes biodiesel production less attractive when oil prices are low (below 50 USD/barrel).
Renewable energy for local development	Jatropha oil production has not been successful as a biofuel in this project, as has been the case in all other Jatropha projects supported by the Energy Facility
Support to and expansion of Malindi Bio – Fuel Cluster – Jatropha farming	The Kenya Forest Research Institute (KEFRI) supported the project but their interest waned as international and local experience began to show the disadvantages of Jatropha. Low yields from Jatropha farming have also meant decreased interest from local farmers during implementation. The pro-ject is most likely not sustainable.
Jatropha energy system – JES	At present, the project has not begun producing significant jatropha seeds.
Up scaling access to integrated modern energy services for poverty reduction	It appears that the yield from Jatropha plants in the area is much less than foreseen, thus creating a problem, if the generators then have to run on diesel which is more expen-sive than the foreseen rate of Jatropha oil.
Provision of modern, affordable and sustainable energy services to rural poor communities in West African countries from Jatropha curcas oil: an integrated approach based on technological transfer and capacity building improvement	The project implementation team did not acknowledge the consequences of their failure to produce jatropha oil by the end of the project implementation. The improbability of being able to produce enough adequate oil from the seeds planted by project completion has significant economic im-plications and has affected most other elements of the project.
Développement de référentiels tech-niques et économiques pour les filières d'accès à l'énergie à partir de Jatropha en Afrique de l'Ouest	The production (in ha, number of plantations, seeds, oil) has been much less than the objectives. Then, the number of motor quality oil beneficiaries was minimal. The falling petrol prices made it less expensive than the jatropha oil, which affects the project relevance.
Mini-réseaux ERD au gasoil-huile de Jatropha dans le Nord du Sanmantenga au Burkina Faso	As regards the jatropha seed value chain, its use as a biofuel is not competitive given the low gasoil prices.

Contrary to one of the arguments advanced in the 2000s to support Jatropha cultivation, Jatropha needs water and agricultural input, and is sensitive to harmful insects and pest. A number of diesel engines for cars and generators have been transformed to use Jatropha oil but, given the high production costs of Jatropha oil (or derived biodiesel), they do not use it because of the high oil price, lack of sufficient amounts of oil, need for technical control.

On the other hand, Jatropha oil can be used in a number of uses: soap production, bio-pesticides, use in lamps and furnaces. By products such as the press cakes and shells can be valorized. In regions where Jatropha was traditionally produced and transformed, these uses have been seen to compete with the expected energy use of the plant.

The project, *Développement de référentiels techniques et économiques pour les filières d'accès à l'énergie à partir de Jatropha en Afrique de l'Ouest*, envisaged, among other things, the production of 1,237 tons Jatropha seeds per year by 2350 farmers. At mid-term, 15% of the seed production objectives was attained (7% of the initial objective), and 3% of the oil production objective was reached. Conclusions, at the end of the project, although a final evaluation is not available, show that the targeted farmers number have been reached but the production, in terms of hectares, plantation numbers, seeds and oil production are much below the objectives.

However, technology improvements were realized: in the transformation process and in the oil quality and the project resulted in the first HVP quality standard in Mali. In Benin, the project equipment initially designed for processing Jatropha seeds, was tested for neem (a local variety) oil. Another EF project, *Mini-réseaux ERD au gasoil-huile de Jatropha dans le Nord du Sanmantenga au Burkina Faso*, is doing similar experiments with desert date that are abundant in that area.

Conclusions on EF Jatropha projects run implemented in Sub-Saharan Africa:

- Oil production for use in engines, lamps and furnaces is not yet viable, because the cost of production is higher than the price of the fossil alternative (kerosene, petroleum, diesel etc.). Then the production of bio-diesel is no more viable.
- The yield (seeds) per plant is low and the time to reach full maturity is too long (seven to eight years).
- Jatropha harvest time competes with the main food crops one, generating workforce shortage.

Current trends and paths forward concerning the energy-agriculture nexus

Agricultural development is often, in ACP countries, an issue of food security and food sovereignty[13]. Food security and energy security are closely interrelated since energy access is a must for modernizing the production, and developing transformation, storage, product distribution value chains. Problems of energy access is rural areas are one of the main obstacles to those value chains competitiveness, to the agricultural transformations, and to job creations in the sector. Therefore, new balances have to be found between agricultural production and energy access, using energy mixes adapted to the local conditions.

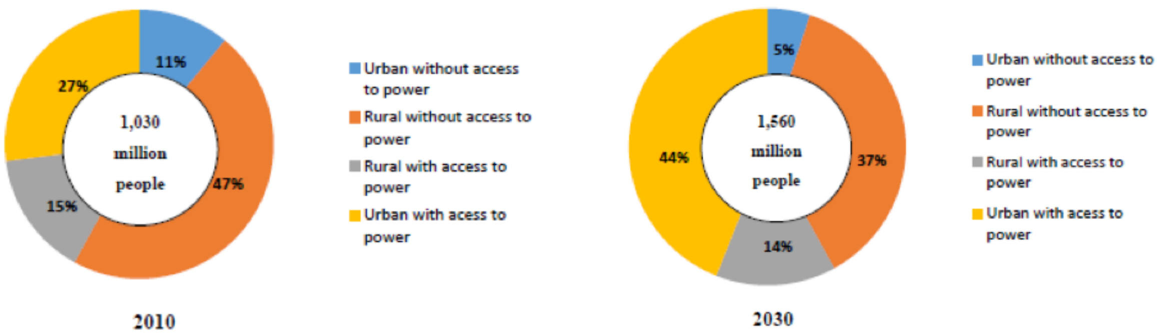

Figure 1: The rural and urban electricity access for people living in Africa for the year 2010 and 2030 (IRENA 2013)

The above figure shows the trend of rural populations in Africa living with / without access to power between 2010 and 2030. With the 50% population increase and despite the relative stability of rural population without access to power, the proportion of population with access to power significantly decreases. Against this challenge, large efforts are made to improve energy service to households, mainly through cooking and lighting, but much less has been done, even in the framework of EF projects, for the development of energy service for agriculture. Joint energy-agriculture policies should be developed and pursued, in order to promote income generating activities for rural populations and break the vicious circle of poverty.

[13] Food sovereignty is a term that emphasizes local communities' control over the way food is produced, traded and consumed.

Joint energy-agriculture initiatives for deeper development impacts

Energy access projects often target households. In rural areas, a parallel priority should more systematically be given to income improvement through a better energy access to agriculture and the agriculture products value chain. In this way, the energy projects address the main economic factors in the rural areas and perspectives of impact and longer-term sustainability increase. Clear indicators measuring the impact and sustainability of increased energy access into the agriculture and agriculture products value chain (conservation, transformation and marketing), could be developed so that relevant projects proper monitoring could be ensured.

Solar technologies

Special attention should be paid to solar technologies, which can offer solutions in several parts of the value chain. A good example is given by the project, Amélioration des conditions de vie des enfants et de leurs familles grâce à un accès à des services énergétiques modernes, propres et abordables dans 30 communautés pauvres du cercle de Kita au Mali. With the objective of increasing and improving the access to modern, clean and affordable domestic and productive energy services, the project installed, among others, 30 solar pumping systems, 30 solar grinding systems and 60 solar dryers. As a result, 100% of the target population benefit from better social infrastructures including pumped water for the gardens, 51% of the 30 female groups members have increased their revenues thanks to the exploitation of solar dryers and PV mills, 28% of agriculture products are transformed through the use of solar dryers.

Developing biofuels

The problems encountered with Jatropha should not be the tree that hides the forest. Developing biofuels remains a central issue for especially Sub-Saharan Africa (Amigun et al.). With most countries importing oil, in a context of volatile oil prices, with an expected doubling population between now and 2015, Africa desperately needs a strong energy sector and biofuels still represent a great opportunity as well as risks.

Strengths, weaknesses, opportunities, and threats of biofuels in Sub-Saharan Africa[14]	
Strengths	Reduction in imported petroleum oil Reducing the dependency on fossil fuels Carbon sequestration Reducing greenhouse gas emissions Energy security
Weaknesses	High capital costs Low energy yields Requirements for large hectares of land Fertilizers and pesticides affect the ecological systems Ineffective governing policies
Opportunities	Increased job opportunities Increased income for rural people Diverse fuel options Infrastructural development Increased electricity supply
Threats	Reduction in the availability of land Affects the soil fertility Food insecurity, if edible feedstocks are used Some feedstocks require high water content

[14] Amigun et al. Biofuels and sustainability in Africa. Renewable and sustainable energy reviews

To support the development of sustainable biofuels, several aspects need to be addressed. Just to name three:

1) Land tenure needs to be secured so small holders are not pushed out of their lands;

2) Assistance to farmers to invest in sustainable land management and conservation, raise yields and make their agriculture resilient to climate change;

3) Building capacity in indigenous expertise, modern farming techniques and high yield and resilient seed varieties;

Conclusions and lessons learned

More energy input is necessary to increase the output of crop cultivation in the developing countries, including the expansion of arable land. Here, irrigation plays a central role and the various water pumping systems (mechanical, wind, solar, etc) should be best adapted to the local conditions. It is of key importance that sustainable management is put in place with a clear understanding of longer-term costs of operation (including replacement of equipment), ability to handle repairs, and established fees are all in place for local irrigation systems to be successful.

For local populations to reap the full benefit of agriculture and receive more substantial added value, the products should more systematically be transformed locally. This again means increased energy inputs for the transformation (milling, grinding) and the storage (cold storage and drying).

In the initial / feasibility study-phases of energy access projects, preliminary studies should assess the energy needs of the complete agriculture value chain, including the production and the transformation of crops, in addition to the needs of households.

In the case of irrigation, sound business models that balances revenue from user fees with long-term costs of operation, maintenance and repairs are the critical point for achieving sustainable impact. In the case of processing and transformation, access to markets is the crucial ingredient.

Simple technologies that can be used for water pumping (mechanical wind for instance) or fruit drying (thermal solar technology) should be prioritized when they offer the opportunity for developing local industries or SMEs (to manufacture and/or repair the equipment). Some experiences also point to that selling of fertilizer from biogas-digesters can be very profitable, but that will depend on local conditions and it is still too early to assess the larger scale potential.

Jatropha should not be promoted as an energy crop unless agronomic research has produced break throughs on improved varieties. However, biofuels as such will most likely still play a role in the future and lessons from the jatropha experience must not be forgotten.

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Annex

Table of EF related projects

		Contribution to agricultural value chain					
Contract number	**Project title**	**Water pumping and irrigation**	**Fertilizer from biogas production**	**Solar drying**	**Cold storage**	**Mechanical processing**	**Energy crops**
2007/195-952	Provision of renewable energy to 3 villages in Ambae Island, Penama province, Vanuatu, using locally produced copra oil as biofuel					x	x
2007/195-953	Provision of renewable energy to two villages in Vanua Lava Island, Torba province (Vanuatu) using locally produced copra oil as biofuel					x	x
2007/195-955	HydroBioPower: livelihood improvement in rural area through collaborative development of renewable energy sources in Oromia and Southern Nations Regional States of Ethiopia		x				
2007/195-959	Desarrollo local de la zona fronteriza dominicano-haitiana a través de la reforestación con Jatropha curcas y la producción al nivel comunitario de energía renovable a partir de biomasa vegetal						x
2007/195-964	Best Ray (Bringing Energy Services to Tanzanian Rural Areas)		x				
2008/195-967	Promoting use of sustainable energy in Wajir District	x					
2007/195-982	Up scaling the smaller biogas Plants for agricultural producers and processors		x				
2007/195-985	Up scaling access to integrated modern energy services for poverty reduction					x	x
2007/196-011	SETUP: Services Energétiques et Techniques à Usage Productif au Bénin			x	x	x	x
2011/231-887	Provision of efficient, affordable and sustainable energy for cooking and heat to rural households in Eritrea						x
2011/232-318	Rural Sustainable Energy Development in Zimbabwe	x					
2011/232-430	Renewable energy for local development	x				x	x
2011/232-620	Support to and expansion of Malindi Bio – Fuel Cluster – Jatropha farming					x	x
2011/262-124	Mini-réseaux ERD au gasoil-huile de Jatropha dans le Nord du Sanmantenga au Burkina Faso					x	x
2011/262-519	Développement de référentiels techniques et économiques pour les filières d'accès à l'énergie à partir de Jatropha en Afrique de l'Ouest					x	x

Table of EF related projects

		Contribution to agricultural value chain					
Contract number	**Project title**	**Water pumping and irrigation**	**Fertilizer from biogas production**	**Solar drying**	**Cold storage**	**Mechanical processing**	**Energy crops**
2011/264-691	Energies durables dans les régions d'Agadez et de Tillabéri			x		x	x
2011/264-851	Jatropha energy system – JES	x					x
2011/265-611	Provision of modern, affordable and sustainable energy services to rural poor communities in West African countries from Jatropha curcas oil: an integrated approach based on technological transfer and capacity building improvement	x				x	x
2011/267-136	TRIODOS – Expanding Sustainable Energy Markets through Microfinance-Energy Enterprise partnerships		x				
2011/268-336	Integrated Approach to Meet Rural Household Energy Needs of Ethiopia						
2011/270-635	ProgettoMondo Mlal : – Déployer de nouvelles opportunités de développement socio-économique par l'accès aux énergies durables dans le Plateau Central		x	x			x
2011/273-991	Programme d'accès aux services énergétiques, Commune rurale SAFO (PASE)	x					
2014/342-830	Production décentralisée d'électricité et Valorisation de l'Electrification Rurale pour l'Agriculture et le Développement Rural au Cameroun (Plan VER)						x
2014/344-468	Programme d'Implantation et de dissémination de Biodigesteurs dans les zones rurales du Sénégal (PIDB)		x				
2014/348-755	Sustainable Energy for Rural Communities (SE4RC)	x					
2014/352-925	Somali Energy Transformation (SET) Project	x					
2014/352-933	Amélioration des conditions de vie des enfants et de leurs familles grâce à un accès à des services énergétiques modernes, propres et abordables dans 30 communautés pauvres du cercle de Kita au Mali	x		x		x	
2014/353-512	Accès à des services énergétiques modernes et durables au Mali	x	x				
2014/351-553	PROGRES-Lait : Programme Régional d'Extension de l'Horizon des Opportunités de Valorisation de la Chaîne de valeur Lait par l'Accès aux Services Energétiques durables				x		