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Urban Food-Waste-Energy Nexus and the Private Sector

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Briquettes production. Photo by Maurice Kamate

The Food-Energy Nexus is Closer to our Heart than we might think

Pay Drechsel

Reflecting on the food-energy nexus, my first thought went to the Haber–Bosch process. Perhaps no other human invention has had a more dramatic impact on our wellbeing and mother Earth than the Haber-Bosch chemistry. As the reader might know, and I am citing here largely from Wikipedia, the Haber-Bosch process is the main industrial procedure for the production of ammonia fertiliser today. It is named after its inventors, the German chemists Fritz Haber and Carl Bosch, who developed it in the first half of the 20th century.

The process converts freely available atmospheric nitrogen into ammonia under high temperatures and pressures. The process produces over 90% of the globally used nitrogen fertiliser, mostly in the form of ammonia, ammonium nitrate, and urea. The downside is its high energy demand, consuming 3-5% of the world's natural gas production (around 1–2% of the world's annual energy supply), or as another source put it, the annual energy consumption of all German households combined.

On the plus side, these fertilisers (in combination with pesticides) have quadrupled the productivity of agricultural land. Without this, nearly half of the world's population would not be alive today or the world would have required nearly four times more land to feed us, rather than under 15% of the total land area that is required today. Thus, for several decades, virtually all the fixed nitrogen added to our farms has come from these synthetic fertilisers, feeding a third to half the present world population, which also implies that **on average half the nitrogen in each of our bodies and its protein, is of artificial generation** thanks to Haber and Bosch. Wikipedia even states that nearly 80% of the nitrogen found in human tissues originated from the Haber-Bosch process. If we read then that also 83% of our global tap water – in particular in the most developed countries - contains microplastic fibres, which might accumulate in our organs or could at nanoparticle size penetrate our cells, we have to realize that our industrial blessings are closer to our heart than we might have thought.

Aside the impact on our energy reserves, the synthetic nitrogen fertiliser production also impacts on the nitrogen cycle, and this is actually larger than mankind's effect on the carbon cycle. We convert today more nitrogen gas into fixed forms than all the Earth's processes combined. For a balanced nitrogen cycle, the added ammonium has to be again unfixed. In nature, nitrogen-fixing bacteria are balanced with denitrifying counterparts in roughly equal proportions. The Haber process brought this balance out of any proportion, and a group of scientists led by Johan Rockstrom, who also chairs the CGIAR program on Water, Land and Ecosystems, led by IWMI, explored the questions of **planetary boundaries**. And in this analysis the nitrogen cycle disruption received the red flag to have crossed the safe limit, as a significant fraction of the applied nitrogen (and also phosphorus) becomes pollutants of air and water sources including the sea, and can push marine and aquatic systems across ecological thresholds of their own. The nitrogen-related disruption of the terrestrial and aquatic ecosystem functions and contributions to global climate change have significant environmental cost, which have been estimated between Euro 70 to 320 billion per year just for the European Union.

We know for long that synthetic fertilisers have aside many benefits also their ecological downsides. But their stake in the food-energy nexus and our own body gives food for thought. We might not be able to avoid finding Haber-Bosch captured nitrogen also in manures and organic residues used for composting. However, from a life cycle analysis perspective the energy savings of a more biological "reduce, recover, recycle and reuse" concept would help make crop production more sustainable than asking for new fertiliser. This is exactly where organic farming, the transformation of excreta into fertiliser and many urban backyards and community gardens are best placed to spearhead a more energy-conscious food production.

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Editorial

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Photo by René van Veenhuizen

Rapid urbanisation and increased economic growth – coupled with increased consumption levels – are driving up the demand for energy, water and food in developing countries. The centrality of access to affordable and sustainable energy to economic prosperity and sustainable development in developing countries cannot be overemphasised. Energy security plays a key role in sustaining development. It affects all facets, social, economic and environmental, as well as all sectors of the economy in terms of food production, health, clean water, employment and gender equality. By 2050, the demand for energy will nearly double globally (INRENA, 2015). But about 1.1 billion people remain without access to electricity and 2.9 billion people still rely on traditional biomass fuels such as fuelwood, charcoal and agricultural residues as their source of fuel for cooking or heating (UNDP, 2016).

The ability of existing water, energy and food systems to meet growing demand is constrained. Cities and metropolitan regions need to respond to multiple challenges of ensuring adequate access to food and energy for their population; they have to sustain local economic development and sustainably manage resources while addressing the challenges of climate change adaptation and mitigation. There are negative impacts from conventional energy sources and limited capacity of current energy infrastructure. Together with the increase in energy demand, these factors have spurred interest in promoting alternative sources of energy. These include harnessing energy from the sun or promoting a circular economy which builds on short cycles, resource recovery and reuse.

It is widely recognised that recovering energy, water and nutrients from various organic waste streams is essential to ensure energy security and sustainable development in both urban and rural sectors. However, these solutions face numerous barriers such as high investment cost, inadequate policy support and implementation, lack of financial means and lack of revenue-generating or cost-recovery models. These constraints are exacerbated by the complex interactions and interconnectedness of resource use and management between different sectors of the economy.

With innovations in technology adoption and operations, through a combination of institutional and financial arrangements, businesses can be a vehicle for managing water, nutrients and energy. But currently there is inadequate knowledge about the nexus of water, energy and nutrient footprints on food production. And coupled with the inability to capture value from waste streams, the result is lost opportunities.

This issue of the UA Magazine discusses this urban-food-energy nexus with a focus on the role of the private sector. Emphasis is on its enabling environment in promoting a circular economy. This UAM shares experiences and cases from several sources. The West-African Bio-wastes for Energy and Fertiliser (WABEF) project complements a recent study done by RUAF for the Dutch Food Business Knowledge Network on the role of the private sector and social enterprises in shaping or enabling city region food systems. It also features experiences from the Resource Recovery and Reuse programme of IWMI (the CGIAR Research Program on Water, Land and Ecosystems). Lastly it includes information from projects of RUAF and its partners on the safe recovery and use of energy, water and nutrients from waste streams, such as from Ghana, Gaza and Nepal, and from HIVOS and SNV.

Wind, solar, hydro, geothermal, and biomass resources are often widely available. There is potential to produce bioenergy from food processing plants, or by linking sanitation and biogas, or in briquette manufacturing as an alternative to fuel wood (see articles on pages 26 and pages 36-43). The re-use of organic wastes as agricultural fertilisers and energy using biogas technologies, requires proper management of these resources. To make this possible, governments should introduce a systematic approach to the collection and dissemination of statistics on organic wastes at various levels and sectors.

The interlinkage between the water, energy and food systems - the nexus - refers to the design of sustainable solutions in identifying and pursuing synergies between these sectors, enhancing performance, management of resources and supply of services (see p6). Energy supply accounts for nearly 15% of global freshwater withdrawals annually (INRENA, 2015). 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. Renewable energy-based desalination or irrigation technologies could play an increasing role in bridging the water gap. Solar energy may cater to the electricity needs of irrigation, desalination or of cold storage facilities and processing units in agricultural chains (see article on page 44).

Although the contribution of renewable energy to the total energy supply and use is still relatively small, it does offer opportunities to accelerate the transition to cleaner energy services in the regions where affordability and accessibility to modern energy services are far behind expectations (see articles on p11-25 and on p29). Decentralised renewable energy solutions play a crucial role in the provision of access to modern, reliable and affordable energy services in rural and remote areas in Sub Sahara Africa. However, the investments in renewable energy mini-grids or stand-alone systems have not reached economies of scale. Traditional biomass is often foraged, which demands considerable time and labour, particularly affecting women. The deployment of renewable energy services will increase access to sustainable cooking and heating devices, affordable lighting, or refrigeration and productive activities, while at the same time improving public health and the position of women (see articles on pages 33, 36-43 and 44).

When managed sustainably and efficiently, the development of – various mixes of – renewable energy may create new markets and generate employment opportunities that could positively affect incomes and poverty reduction. These can at the same time contribute to environmental objectives. On pages 52-59 results of a study done with the Dutch Food Business Knowledge Network are presented. These describe the role of the private sector in helping to shape more sustainable city region food systems and the kind of business and policy environment that is needed to better engage the private sector in building these city region food systems. The types of businesses that are involved in the city region food system come from across the entire food supply chain. Non-food system actors play an increasingly significant role. They are adopting innovative nexus approaches to addressing issues such as finance and livelihoods, health and housing provision, supporting social enterprise development, managing natural resources and dealing with the urban metabolism. Development towards a more sustainable city region food system requires more than just supporting individual businesses. It is important to stimulate integrated planning and coordination processes to overcome sectoral approaches.

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Making Sense of the Urban Nexus: An integrated approach to intersecting challenges

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Nashik periurban agriculture. Photo by ICLEI

Cities are sites of complex and intersecting challenges which threaten the success of the global sustainable development agenda. All over the world, cities face persistent challenges related to increasing climate- and weather-related impacts, insufficient infrastructure, sustained poverty and inequality, resource scarcity, and sustainable service provision. Finding solutions to these challenges will be made even more difficult by growth and migratory flows between cities, both of which are forecast to increase significantly for the global urban population over the next three decades. As the total number of urban dwellers increases, greater demand will be placed on peri-urban and rural land – both for productive activities and for human settlements.

The scope of these shifts within a global context of climate change and limited resources will create immense challenges for the institutions responsible for providing basic services, ensuring economic prosperity and managing resources. Mostly, these provisions fall within the mandate of local and regional governments. Cities do, however, provide a context for systematic linkages between sustainability outcomes (social, environmental, economic) and resources (water, waste, energy, agriculture) to be identified and harnessed through an integrated approach to urban development.
Traditionally, the governance and management of resources has been carried out through sectoral departments or dedicated agencies that operate in isolation; this has resulted in excessive waste and necessitated increased reliance on external inputs. In order to ensure that the growth which occurs over the next century does not overstep the planetary boundaries within which humankind can continue to develop, a governance and resource management approach which integrates across sectors and scales is needed. This represents a significant conceptual shift, requiring thinking of cities as being embedded in the ecological, social, cultural, political and market-based environment in which they are located.
Urban infrastructure is a major determining factor for efficiency within energy, water and materials cycles. Local and regional governments are uniquely positioned to coordinate these integrated solutions by establishing inter-sectoral and integrated urban management systems. They can introduce institutional arrangements, enact new policies and raise awareness. In addition to urban infrastructure, multiple productivity factors – including labour and capital markets and research institutions – exist within the city-region context. The impacts of enhanced productivity within city-regions can address each of the three pillars of sustainable development (social, economic and ecological).

Introducing the urban nexus

In 2014, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and ICLEI – Local Governments for Sustainability – published "Operationalising the Urban NEXUS: Towards resource-efficient and integrated cities and metropolitan regions". Building on existing approaches to integrated management, the NEXUS approach offers a

methodology for identifying and evaluating potential integrated planning solutions.

The NEXUS methodology leads stakeholders through a process in which they identify and pursue connections – termed 'nexus points'. These points exist across supply chains and resource cycles, technical departments and political jurisdictions. Because the NEXUS approach considers the extent and articulation of urban systems, nexus points can be identified at different scales – ranging from a local asset to a global phenomenon. The goal of applying a NEXUS approach is to improve resource efficiency, service quality and access to services. In delivering greater benefits while using a smaller amount of resources, it is possible for cities to reduce their reliance on external inputs; a reliance which threatens to overrun our planetary boundaries.

The Urban NEXUS model begins with setting objectives: the identification of targeted increases in organisational and resource productivity that the NEXUS initiative is going to address. The next step involves examining scales, systems and resources, services and facilities, silos and social behaviours. This step helps to identify the possible benefits of integrating two or more of the operations or systems that intersect at an identified nexus point. Following this, a development cycle is created, detailing a process for innovation, solutions design and delivery, capacity building and communication, and evaluation. Lastly, the measures and reforms required to enable the NEXUS solution are detailed: institutional development, legal and policy interventions, design and technology advances, new delivery models, and shifting user behaviours.

Translating theory into practice

As part of the GIZ & ICLEI project, the Urban NEXUS was operationalised in two pilot project cities: Nashik, India, and Kinondoni Municipality in Dar es Salaam, Tanzania. Although the project only allowed a limited timescale for implementation, application of the Urban NEXUS methodology managed to generate a new 'institutional nexus' by convening a number of key stakeholders that had not previously sat together. Interventions in Kinondoni focused on improving the quality of the learning environment at two local public schools through the installation of integrated energy-efficient technologies and the introduction of rainwater catchment devices and vertical food production systems. Interventions in Nashik included the collaborative design and implementation of solutions for optimising the use of water, energy and land resources within peri-urban agriculture.

The GIZ & ICLEI study detailed the extent to which local and regional governments around the world have already begun to look for linkages between the water, energy, food, and waste sectors. Food is an excellent place to begin when looking to create productive cities. It provides a vital link between cities and rural communities. It offers a key opportunity for addressing hunger, poverty and unemployment, climate change impacts and environmental degradation. Agriculture is both water- and energy-intensive, and efficiency measures in the food sector can help save energy and water, and reduce waste. Local and regional governments have considerable leverage over several facets of a city-region food system, from nutrition and health to economic development, to land use and resource management. Yet few of them integrate food in a cohesive manner across their different thematic departments, or maximise its potential in service of their constituencies.

The CITYFOOD Network

The ICLEI-RUAF CITYFOOD network aims to accelerate local and regional government action on sustainable and resilient city-region food systems. It combines networking with training, policy guidance and technical expertise. CITYFOOD is open to local and regional governments, whether they are engaging with the issue for the first time or working to implement the Milan Urban Food Policy Pact. The latter is at the frontier of innovative food systems work. CITYFOOD is active in both the Global North and South and will build a strong south-south-north exchange platform for learning among cities. It will establish direct connections with people on the ground and staff engaged in policy development. www.ruaf.org

Mainstreaming the nexus

The emphasis on stakeholder involvement within the design of Urban NEXUS solutions means that an intervention developed for one location may easily be transferable to another. Facilitated knowledge sharing and peer-to-peer learning are nonetheless invaluable tools to ensure that the exchange of respective good practices occurs.

The ability to learn from peers is particularly important when considering the legacy of 'blind' transfer of urban planning and resource provision models from the Global North to the Global South. These transfers are often structured through official development cooperation and reflect investments created by international financial institutions. They frequently fail to take existing local practices and relationships into account. Far too often, the emphasis is placed on solution implementation rather than solution design. Peer-to-peer learning offers the opportunity to share experience of what makes a solution operational within a particular context and how to negotiate a solution with key stakeholders and partners.

The Urban NEXUS approach itself is built upon previously-established integrated planning concepts and various examples from local and regional governments. To help mainstream and multiply this process across local and regional governments and within a resource-specific work stream, ICLEI and RUAF have launched the CITYFOOD network.

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Waste-to-Energy Business Models: Insights from a compendium of business models

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Photo by Jean Michel Médoc

Recovering energy, nutrients and water from domestic and agro-waste streams is gaining momentum as a new agenda for promoting sustainable development in developing countries as waste management strategies shift focus from a *disposal-oriented* approach to *a business-oriented* approach. The latter approach emphasises *value creation* and *revenue generation* (Murray and Buckley, 2010). As most cities in developing countries struggle with the challenge of energy security, recovering energy from different waste streams offers dual benefits – improved waste management and provision of reliable energy to households, institutions and commercial entities.

The International Water Management Institute (IWMI) has identified and analysed a number of waste-to-energy business cases across the globe and, based on these cases, has developed a number of waste-to-energy business models with potential to be scaled up in different settings and contexts (see link for business model profiles https://wle.cgiar.org/rrr-business-model-profiles). In this article we highlight the factors that drive but also may inhibit the success and sustainability of selected waste-to-energy business cases in different countries.

Waste-to-energy businesses can be categorised into different typologies based on such factors as type of value proposition offered by the business, the revenue generating mechanism, the type of partnership and ownership structure and the type of waste input and energy product recovered. In order to understand the waste-to-energy conversion processes, it is important to consider three components of the process: the waste stream, the energy product and the end use, as shown in Figure 1. The waste streams come in a variety of forms and have different properties that impact their use for producing energy products which come in solid (briquette), liquid (bio-fuel or ethanol) and gaseous (producer gas and biogas) form. These energy products are used to generate heat, electricity and fuel for cooking or for transport.

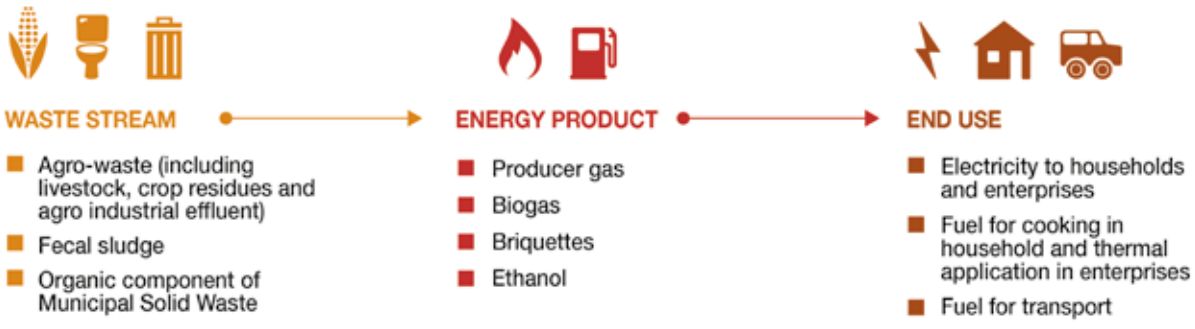

Figure 1. *Waste-to-energy process framework* (Otoo and Drechsel, 2017)

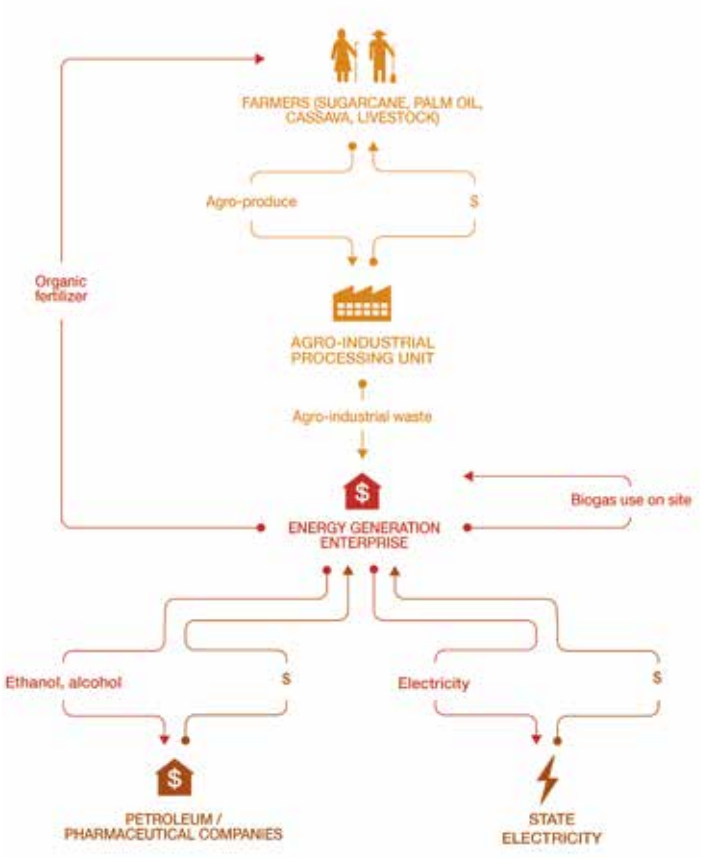

Figure 2. *Process flow for on-site energy generation by agro-industries* (Otto and Drechsel, 2017)

Different entities are developing business models around these waste streams and end products. Waste-to-energy businesses are either owned by the public sector, with the objective of cost-recovery for the sanitation sector and potential for revenue generation, or by private sector enterprises, with the objective of cost savings for profit maximisation. These businesses are also sometimes run on a public-private-partnership model or a social enterprise model, where the business is driven not by profit maximisation but by the aim to maximise social welfare. For this article, we have selected waste-to-energy business cases which also have a link to agriculture, bringing in focus the waste-energy-agriculture nexus.

Cost recovery in institutions through on-site energy generation

One of the most common waste-to-energy solutions that is widely implemented in developing countries is biogas production. While household biogas installations are very common, experience in institutional biogas systems is limited but is gradually gaining traction in Asia and Africa. Energy recovery from fecal sludge and kitchen waste through the installation of biogas systems has been a success in institutions such as schools, hospitals, prisons and other institutions consisting of large number of residents. These on-site energy generation models provide institutions the opportunity to save on energy costs by using energy produced on-site for cooking and heating (Box 1). Biogas generation for on-site use can also be coupled with digestate (the by-product of biogas generation) application on land thus, returning nutrients from waste to the soil.

Box 1

Onsite energy generation at prisons: Rwanda, Nepal, Philippines

The International Committee of Red Cross (ICRC) under its water and habitat unit has implemented numerous institutional biogas systems across prisons in Rwanda, Nepal and Philippines in partnership with local organisations. Local partners include Kigali Institute of Science, Technology and Management (KIST) in Rwanda, Biogas Sector Partnership (BSP-N) in Nepal and Practical Action consulting in Philippines. The prison biogas systems aim at reducing prison costs, reducing wastewater pollution and improving prisoners' lives through the installation of biogas systems. In Rwanda, dissemination of large-scale biogas digesters to prisons has registered significant success. The initiative by KIST won the Ashden Award for Sustainable Energy in 2005. Currently KIST has installed biogas digesters in several prisons in the country.

The key value proposition of on-site energy generation in prisons is to provide improved sanitation service to prison inmates. In the process the system provides two additional value propositions, a) biogas as a cooking fuel and b) bio-slurry (digestate). Biogas replaces firewood which is the common cooking fuel in those institutions while the digestate is used on-site for growing crops and trees. These result in savings for the running of prison operations in terms of money spent on firewood and fees for emptying sceptic tanks.

A government ban on the use of firewood (as is the case in Philipinnes) was a catalyst to innovation, while partnership with local expertise and provision of technical and business training to local communities constitute important prerequisites for sucessful implementation and for ensuring sustainability of the on-site energy generation model.

Agro-processing by-product value addition through on-site energy generation

On-site energy generation can also be implemented by agro-industries through the installation of different technologies. Many major agro-industries such as sugar processing factories, cassava, palm oil and slaughterhouse industrial factories in developing countries are diversifying into agro-processing by-product value addition through co-generation. Energy generation from agro-waste is driven

Box 2

Strict enforcement of environmental regulations as a catalyst to innovation

The Nyongara biogas plant in Kenya, where slaughter house waste is processed to produce biogas, is a good example of how strict enforcement of environmental regulations by the National Environmental Management Authority (NEMA) has induced the slaughter house unit to have a businessoriented solution to its waste management problem. The waste generated by the slaughter house units around Dagoretti, an area famous for the presence of slaughter houses on the outskirts of Nairobi, was polluting Nairobi River. As a consequence, NEMA was closing slaughter house units that were not meeting the regulatory norms of treating their waste. Thus, to manage its slaughter house waste and to comply with the NEMA regulations, the Nyongara biogas plant was established.

The biogas plant began operations in 2011 with biogas used both for heating and to generate electricity primarily for refrigeration and lighting purposes. The digestate from the biogas plant is high in nutrients and is used in cultivation of tomatoes within the slaughter house. Nyongara slaughter house is planning to scale up the biogas plant and its operations to process slaughter house waste from other slaughter house units and thereby generate biogas and sell the electricity back to the same slaughter house units.

by the need for agro-processing units to reduce their energy costs through the use of energy on-site and also to explore new revenue streams from selling excess energy in the form of electricity and ethanol (Figure 1). The energy production technologies are either designed, constructed, owned and operated by the agro-industrial processing factory or are installed by an external private entity on a Build, Own, Operate, Transfer (BOOT) model. This business model has a multi-value proposition as it not only allows agro-industries to be self-sufficient in energy while disposing of their waste sustainably, but also to secure additional revenue streams by exporting excess electricity to the national grid as well as trading of carbon credits (cgspace.cgiar.org/rest/bitstreams/119776/retrieve).

Promoting waste-to-energy businesses through a conducive investment climate

Policies, regulations and institutions play crucial roles in the successful implementation of on-site energy generation models; appropriate national policies, programs and fiscal incentives can be critical to success. On-site energy generation models in agro-industries have been successfully implemented in Latin American, African and Asian countries. For example, a number of policy reforms in the Kenyan power sector have liberalised the energy generation sector thereby paving the way for independent power producers (IPPs) such as Mumias Sugar Company (MSC) to participate in power generation. MSC took advantage of its co-generation potential from sugarcane bagasse by generating 38 MW, out of which 26 MW is exported to the national grid. Other sugar companies are expected to diversify into the use of sugar processing by-product value addition through co-generation and bioethanol production. Similarly, a number of domestic and international programmes to support bagasse-based co-generation were launched in India, which promoted the advancement of co-generation plants. These support programmes include extension of loans for co-generation by Asian Development Bank (ADB) through the Indian Renewable Energy Development Agency (IREDA), capital and interest subsidies, research and development support, accelerated depreciation of equipment, a five-year income tax holiday and excise and sales tax exemptions by the Ministry of Non-Conventional Energy Sources (MNES).

In addition to policies and regulations that promote the deployment of waste-to-energy business models, regulations related to the environment if strictly implemented by the national authorities have the potential to result in entrepreneurship in waste management (see Box 2).

The potential for waste-to-energy business models

Waste-to-energy business models have the potential to be replicated across all urban and agro-industries. To that end, there is a need for *business thinking* and *market-driven mechanisms* to motivate their reuse of waste to ensure their economic viability and long term sustainability. This presents opportunities for revenue generation and social benefits for all relevant actors and incentives for private sector participation to ensure their sustainability. Furthermore, policies, regulations and financial schemes that support the starting-up and scaling-up of waste-to-energy solutions are important in facilitating private and public sector investment in waste-to-energy business models, including those that incorporate the agriculture-waste linkage.

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WABEF: Western Africa Bio-wastes for energy and fertilisers

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Biogas Transpaille unit at AEDR, Mali. Photo by René van Veenhuizen

Population growth and urbanisation, along with changes in lifestyle and consumption, lead to large quantities of solid and liquid organic waste from agricultural, agro-industrial and urban activities. In the absence of an adequate waste management system, these can cause harm to human health and the environment. Biogas technologies are unique among renewable energy forms in that they address several challenges in Sub-Saharan Africa in an integrated manner. They enhance the connections and potential synergies between sectors. WABEF – Western Africa Bio-wastes for Energy and Fertilizer - has promoted anaerobic digestion as a way to recycle bio-wastes for energy and fertilisers. As such, the organic matter loop is closed.

At present West Africa has a very low electricity use per capita, but this situation is likely to change rapidly in the future: demand is projected to increase ten-fold in the coming two decades as economic activity increases and universal access is achieved. A power sector transition is required and actually has started. Africa does have an abundant potential of bioenergy in the form of plant and animal residues among others or bio-wastes, which is in principle enough to satisfy the national demand for electricity. But still around 850 million people cook and heat their homes using open fires and simple stoves burning biomass (wood, animal dung and crop waste) and coal. Opportunities exist to use available biomass sustainably.

ECOWAS/ECREEE suggest that up to 54% of Western Africa's power supply can be based on renewables in 2030 (that includes hydro-power). Most ECOWAS countries have set targets of a use of 10% to 20% renewable energy (excluding hydro-power) in 2020 and 2030 respectively.

Adoption of renewable energy in developing economies is growing at about twice the rate of industrialized economies. Renewable energy sources most used for large-scale applications are hydropower, biomass, geothermal, wind and solar energy sources, with these being usually grid-connected.

The technologies needed for tapping into Africa's renewable energy resources are available, reliable and cost-competitive. Various innovative uses of bio-wastes have been introduced and tested, such as domestic or community-managed biogas projects, or using food-wastes or waste from agroindustry. With increased efficiency of use and better technologies, significant power can be produced for local demand or added to the national grid. Several agriculture-based industries in the continent, such as wood-based including paper industries, palm, rice and sugarcane mills use their waste to produce both process heat and power, which in most cases is used locally. Somewhat larger-scale biogas plants also operate successfully in a number of African locations. Most urban areas in Africa face serious problems with disposal of liquid and solid bio-wastes, which could be converted to energy, while also producing organic fertiliser.

Bio-wastes, or "Residual Organic Products", in the broad sense, are biodegradable wastes derived from agricultural, agro-industrial and urban human activities. These include crop residues, manure, slurry, abattoir waste, garden or park wastes, food or kitchen wastes, waste from food processing and sewage sludge.

The potential of using bio-wastes for energy and fertiliser is based on the accumulated bio-waste volumes. However, in most countries this is hardly known and quantified. Policy makers and entrepreneurs lack sufficient information on how and where to start a business or formulate a workable policy. WABEF has therefore developed operational tools for each step of the value chain, as set out below.

Mobilising the necessary investments will require governments and other stakeholders to work towards an environment that is built on an enabling policy and regulatory framework. In 2005, the Biogas Africa initiative was launched in Nairobi. Since then, many stakeholders have engaged in different initiatives and partnership programs supporting development of biogas technology in Africa. Ghana, Kenya, Niger, Burkina Faso, Mali, Ethiopia, Senegal and Rwanda have implemented pilot projects aimed at establishing the technical and socio-economic viability of biogas technology as an alternative source of energy for cooking and decentralised rural electrification. However, only a few countries have managed to start implementing their frameworks.

But there are other hurdles for upscaling and dissemination of good practices in Sub-Saharan Africa. These include constraints on mobilising bio-wastes, high initial investment costs for construction, insufficient maturity of national biogas programs, as well as technical, institutional and socio-cultural barriers.

The WABEF answer

WABEF – Western Africa Bio-wastes for Energy and Fertiliser was a research-development and capacity-building intervention funded by the ACP-EU Science & Technology II programme. Its aim was to recycle organic residues issuing from agriculture, agro-industries and municipalities into energy and fertiliser (http://wabef.cirad.fr).

Biogas technology is unique among renewable energy sources in that promoting its development in West Africa will support the environmental, energy and agricultural sectors:

- It reduces the pressure of bio-wastes on the environment by recycling them into biogas plants; this produces energy for cities and reduces deforestation by limiting the supply of wood and coal from rural areas
- It contributes to the satisfaction of energy needs in a complementary mix with other sources of conventional and renewable energies
- It closes the organic matter loop through the production of bioslurries as fertiliser returned to agricultural production areas; this addresses agricultural productivity and food security issues.

WABEF worked with various target groups, like decision makers, researchers, NGOs and technicians in agriculture, municipalities and agro-industries. Collectively they reached out to communities, students, entrepreneurs, and farmers. The key output of WABEF is a decision-support toolkit on anaerobic digestion of bio-wastes in West Africa.

Activities and products

As a first step WABEF analysed experiences in Europe and in Africa. Thirty-four anaerobic digestion experiences in Europe (14) and Africa (20) were visited by a broad team of representatives from the project partners, to learn about technological and managerial successes and failures, but also political and regulatory incentives and disincentives. It

Photo by René van Veenhuizen.

Photo by Seydou Niang

also assisted in developing a typology of biogas.

WABEF identified the key technical indicator for this typology. It relates the nature of the bio-waste intake with the annual quantity processed in the biogas unit and the electric power delivered. This was useful to compare relevant experiences of: less than 3,000 T/year and 50 kW; between 3,000 and 10,000 T/year and between 100 and 500 kW; and above 10,000 T/year and 500 kW. For each category an experience was documented. (http://wabef.cirad.fr)

Three main lessons emerged out this study. The first is the need to secure the bio-wastes supply to ensure its smooth operation and durability. The second is to have policy and regulatory frameworks that provide incentives for attractive tariffs for the purchase of by-products -- in particular biogas and electricity -- and that promote technologies consuming these by-products. The third lesson, related to the first, is to secure the flow and recovery of bio-wastes in order to minimize the risks of environmental pollution; this also avoids loss of income for the unit and maintains its good reputation.

The development and adoption of biogas as a solution for the management of bio-wastes in West Africa requires a favourable political climate and strong government support; that includes proper financial support for businesses and investment. An integrated approach must also enable proper management of information, an adapted technology chain, and sufficient bio-waste resources: where and when are they available, in what amounts, and with which energy and agronomic potential, and what is the competition? The recycling of bio-slurries must also be facilitated. The compendium guides the reader, whether practitioner, project promoter or policy maker, into these constraints and challenges. It also guides them on the appropriate tools that have been adapted by WABEF to support the assessment of each step of the biogas value chain.

Constraints of biogas development in West Africa and challenges to overcome

Toolbox / decision support systems

As a second step, and relying on the operation of the value chain, the project adapted a variety of existing items to develop a toolbox. This made it possible to characterise or evaluate each step of the value chain and its feasibility (see figure). For each of these steps WABEF proposes an operational tool allowing answers to the questions: *Availability* of bio-wastes? For *which biogas system? What valorisation* for biogas? *Use of bio-slurry* or digestate? Is the whole value chain *feasible?* And what *knowledge and know-how are needed for decision makers and practitioners?*

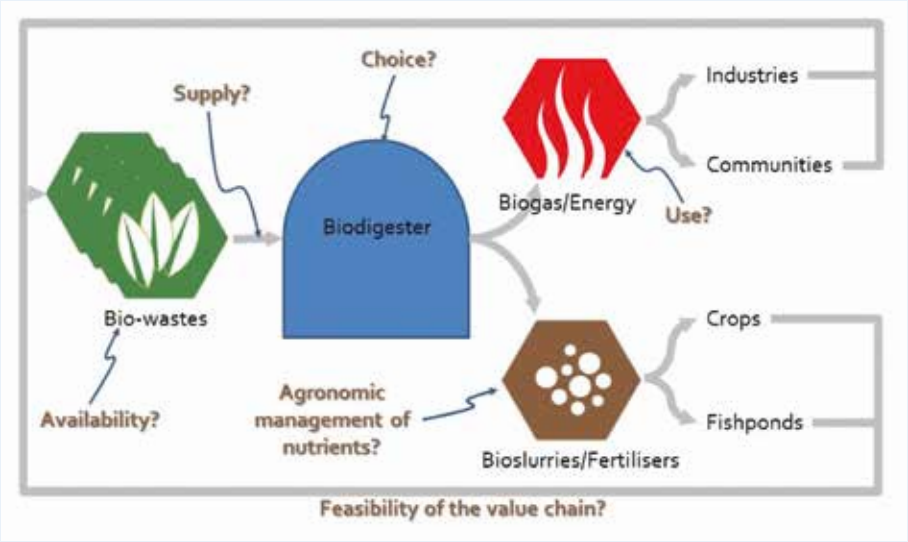

Figure: Questions to be answered to support decision-making and a viable business plan.

Availability of bio-wastes

In West Africa, little information on bio-waste deposits and their quality are available. Their appropriateness raises questions. A method to identify, quantify and assess their potentialities in term of fertilisation and production of biogas has been developed in the form of three databases. These estimate the deposit of bio-wastes from agricultural activities (crops and livestock), the deposit of bio-wastes from municipal activities and the deposit of bio-wastes from agro-industrial activities. Combining available information at district level on livestock and cultivated areas allows one to get a rough or theoretical deposit related to the assessment of the valorisation ratio one reach the agricultural bio-wastes deposits available for biogas. Municipal bio-wastes can be obtained through national census data of population at the district level combined to production ratio of household waste, use of improved or unimproved sanitation facilities

Biogas production depends on the quantity and quality (biochemical methane potential) of the bio-wastes. WABEF has done this in collaboration with *Institut Sénégalais de Recherches Agricoles* (ISRA) and the support of the Biogas National Programme (BNP) of Senegal and.

The data necessary for such calculations are dispersed, often difficult to access, and generally poorly organized. The re-use of bio-wastes as agricultural fertilizers and energy- using biogas technologies requires proper management of these resources. Governments should introduce a systematic approach to the collection and dissemination of statistics on bio-wastes at various levels and sectors, with an identified focal point.

Supply

To answer the question "what supply for a unit of collective biogas?" simulation tools exist (designed by CIRAD, Research Unit *Recyclage et Risque*) and can be used in West African conditions. The objective for a biogas operator is to be able to coordinate the quantity and quality of bio-waste supply to the biogas unit in order to allow its nominal operation. Different supply strategies (planned or reactive) and logistic options (truck number and capacity, route, working time, etc.) can be tested, depending on the characteristics of the biogas unit, including hazards. These strategies and options can be compared using indicators of the amount of residues actually delivered to avoid bio-waste stock shortages at the biogas unit, working time, kilometres travelled). These tools can be used to inform preliminary projects.

Photo by Maurice Kamate

WABEF multi stakeholder meeting in Dakar. Photo by René van Veenhuizen

Biogas technology

The model of technical-economic analysis of biogas: *Methasim*© developed by IFIP (*French Institut du Porc*) has been adapted for use in West Africa. A biogas project owner needs to make a reasoned choice of which technology to implement for a specific context. This tool allows one to test different intake ratios and technical options to calculate mass balances and economic balances for different biogas technologies. The user can then compare them. This tool can support actors in the development of their preliminary project.

Use of biogas

The biogas product from the biogas production process is composed of 50-80% of methane (CH_4), 20-40% carbon dioxide (CO_2) and 0 to 3% other gases such as hydrogen (H_2), nitrogen (N_2), hydrogen sulphide (H_2S), carbon monoxide (CO). This composition is closely related to the composition of the bio-waste intake of the digester. The methane content of the biogas allows the production of energy.

The valorisation of the biogas produced by a biogas unit depends on the purpose for which the unit was installed, the volume of biogas produced, the energy needs of the site and the project holder, possible outlets, etc. The seven uses are (i) heat production, (ii) electricity production, (iii) co-generation (heat and electricity), (iv) injection of bio-methane into the city gas grid, (v) injection of electricity and bio-methane into grids, (vi) bio-methane fuel or natural gas vehicle and (vii) tri-generation (heat, cold, electricity).

WABEF has designed a simple calculation tool to assess the use of the biogas directly or through electricity generation. It is available as a Microsoft Excel® spreadsheet in English and in French. The part of the business plan on financial parameters was more easily placed in a separate sheet that could immediately render the financial results. This was enthusiastically received by practitioners interviewed as they had never obtained such insight in their social business of biogas before.

Agronomic management of released nutrients

After the anaerobic digestion process and its storage, the bio-slurry is sanitised and deodorized. The germination power of weed seeds is also annihilated. The fertilising and soil-conditioning properties of the bio-waste intake are preserved or even optimized in the sense that its major nutrients (nitrogen, phosphorus and potassium or NPK) can be used.

Bio-slurries can be valued as:

- Raw bio-slurry for direct application to agricultural soils. This is the general practice in Europe
- Compost. The raw bio-slurry is composted with a carbonaceous support (straw, wood chips, green waste, etc.) Composting eliminates pathogens that would not have been eliminated during biogas production. And this is the only way, especially in France, to obtain a standardised product that escapes the status of waste regarding regulation
- Liquid fertilising material. The liquid fraction obtained after phase separation can be evaporated or filtered to reduce the water content and produce less bulky solutions rich in nutrients that can serve as liquid fertiliser. This liquid fraction also allows recovery, by stripping nitrogen, of a concentrated solution of ammonium sulphate; and by precipitation of the phosphate and ammonium ions, struvite crystals
- Inoculum. The liquid fraction is reintroduced into the anaerobic digestion reactor to catalyse and stabilise the methanisation process.

Photo by René van Veenhuizen

The utilisation of bioslurries as a fertiliser benefits both farmers and the environment. By applying bioslurries on soils, the nutrients contained in the bio-waste intake are brought back into nature to be incorporated into new organisms and to continue their cycle. By replacing mineral fertiliser with local fertiliser, farmers will enjoy financial gains. The clear picture of the advantages regarding the application of bioslurries as a fertiliser stays, however, in the shadow of regulations – at least for now.

WABEF designed a user-friendly Microsoft Excel® spreadsheet, *Ferti-Mbaay*, a calculator to support farmers fertilising with organic residues including bioslurries. This tool guides the fertilisation of market garden crops, but can be developed to include new crops and new organic residues. The development of this tool raised questions about the availability of the data necessary to implement this simple calculation.

Biogas technologies cannot be developed without institutional support at national and local level. Subsidies for installation of biogas units are needed to support further development and its sustainability, but also mixes of finances for equipment and recovery of by-products (fertilisers and biogas).

Feasibility of the whole value chain

A business model canvas for the biogas system should have the following features:

- Comprehensive in terms of looking at the whole biogas value chain
- Easy to fill in for the practitioners
- Fit both commercial and non-commercially-operated systems
- Provide practitioners and operators with insight on improvement, cost reduction and income enhancement.

WABEF's spreadsheet format (Microsoft Excel®) in French and in English proposes a business model to address the feasibility of the value chain.

Bio-wastes for energy and fertilizer (BEF) business canvas
A business model framework for social enterprises identifies how an organisation can create economic, social and environmental value (Osterwalder, 2004). It turns generic questions into biogas system-specific ones. The model allows for easy manipulation and also the addition of appraisal, monitoring or evaluation numbers. It can then be used to value the information in the reply to the question. The model was tested on the two demonstration biogas systems at AEDR-Teriya Bugu in Mali and at Songhai Regional Centre in Benin. Both are partners of the WABEF project.

Two other qualitative models are suggested to analyse sustainability and maturity.
The FIETS model has been developed in the Dutch WASH alliance project (www.washalliance.nl), and adapted by RUAF. This model aims to assess the progress and sustainability of a project or programme, looking at financial, institutional, environmental, technical and social aspects. This exercise is therefore based on the evaluator's knowledge of the project and should follow a number of suggested recommendations (stand-alone project evaluation, comparison of a range of projects, monitoring and evaluation or post evaluation).

The other tool is developed by the FACT Foundation for larger biogas programmes in Africa. The Product Market Cluster Tool for policy makers and strategists was adapted for WABEF. It looks at the BEF potential and available knowledge to policy makers or strategists, aiming to provide data for policy-makers and strategists to develop adequate policies.

Photo by Maurice Kamate

Any such new activity for a business sector can only be successfully introduced if that sector is stable and preferably growing; this affects the willingness and ability of the business owners to invest in new BEF systems. The strategists or policy makers need to take a number of steps to establish a good basis for policy and strategy development: potential clusters definition; selection of priority clusters; selection criteria to be used; features of the selected clusters.

Biogas can contribute to the energy needs of West African countries as part of a locally-appropriate (renewable) energy mix, while addressing a number of other sectoral challenges. It is therefore important to stimulate integrated planning and coordination processes to overcome sectoral approaches.

An integrated approach

Promoting the integrated development of anaerobic digestion is not to promote one technology or one model, but to offer to the stakeholders the key elements to support reasoned choices for developing an integrated and viable biogas value chain.
The successful fixed domestic dome bio-digester cannot be up-scaled to all localities, especially in urban and peri-urban areas, for reasons of space, safety and public hygiene. But it triggers the start of the sector, and is part of the RE mix.

In West Africa, particularly in Senegal, Mali, Burkina Faso and Niger, wood energy is the main fuel used by 90% of households. Demographic pressure, particularly urban, and poverty intensify this use and contribute to forest degradation. The city of Bamako, 5.4 million inhabitants, consumes 884,491 tons of wood-fired equivalents annually (Fonabes, 2017). Reducing deforestation entails the search for alternatives. Mobilising bio-wastes from municipal solid waste, faecal sludge and sewage sludge to produce biogas in one or more semi-industrial or industrial units could substitute coal and wood for urban populations. The anaerobic lagoon of Ashaiman Slum, Greater Accra, Ghana is an example.

In more isolated rural, domestic and agricultural situations, the small individual household bio-digester can play a role in contributing to the well-being of people, especially women and young people. It creates a better lifestyle through clean cooking and lighting, but the supply of bio-wastes must be secured year-round. At the scale of a rural community or groups of farmers, biogas of semi-industrial size could bring economic development.
Large biogas units require large investments, but they also allow economies of scale and can cover all possible recovery routes for biogas and digestate. But the economic, environmental, social and political sectors must be on the same level of technology readiness.

At local level access to information on the availability of organic resources and the use of by-products are needed. Information as well as access to various sources of financing and appropriate technologies should be facilitated through local incubator centres. The establishment of these decentralised support structures will bring together local authorities, technical services and communities.

Capacity building

WABEF actively disseminated its knowledge in selected countries in West Africa. In July 2017 a regional school was organised at Songhaï (Benin), gathering selected high-level actors from Benin, Cape Verde, Mali and Senegal. They have been trained in the use of the WABEF toolbox and are responsible for further uptake and dissemination. Further information, including a policy brief is available at its website. A curriculum for practitioners and university training will be further developed for dissemination in specific master's programs in West Africa.

The development of biogas in West Africa requires a favourable political climate and strong government support; that includes proper financial support for businesses and households' investment. An integrated approach must also enable proper management of information and waste resources as described above. Furthermore, innovative information and capacity building approaches are needed to support the private sector, governments and civil society to enable wider adoption and dissemination of biogas as part of a further increase in its proportion of RE in Africa.

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Teriya Bugu in Mali

Maurice Kamaté,
Jean-Michel Médoc

Africa has abundant potential of bioenergy in the form of plant and animal residues. This form of energy, when integrated with other renewable forms, not only improves access to energy but also brings rural areas broad-based and inclusive development. This idea has been embraced since the beginning of Teriya Bugu.

Renewable energy in Mali

The energy sector in Mali is characterised by a high dependence on oil. Electrification rates are still very low, especially in rural areas (18% of rural towns and villages as compared to 70% in urban centres). Seventy-eight percent of household energy needs are satisfied by biomass resources (mainly wood and charcoal), which causes health problems from indoor air pollution, such as respiratory infections and eyes diseases. The use of biomass for energy also aggravates environmental degradation such as deforestation and land degradation.

The projected expansion of the national electricity grid is unlikely to connect a significant number of isolated low-income populations in the next decades. There is however both a need and a market for off-grid electrification schemes. Renewable energy (RE) has great potential to address many sectoral challenges as well as to contribute to socio-economic development and poverty reduction. Mali stimulates this RE off-grid potential by targeting all available sources, like solar, hydro, wind and biomass. Various uses of biomass have been introduced and tested in Mali, such as domestic or community-managed biogas projects and bio-ethanol production using sugarcane or biodiesel (Jatropha), but these have only reached a small percentage of the population.

Mali has however restructured and strengthened a number of its institutions in the effort to develop the RE (sub-)sector; this includes the National Agency for the Development of Biofuels (ANADEB). The vision and targets of Mali have been formulated in a number of policy papers, including the National Strategy for the Development of Renewable Energies (2006) and the National Strategy for the Development of Biofuels (2008); both of these were recently updated within the framework of the ECOWAS Renewable Energy Policy (ECREEE). The Government of Mali has also set up the Renewable Energies Agency of Mali (AER-Mali), a public science and technology institution that will provide a structure for monitoring and research as well as capacity development. It manages the Renewable Energy Project that has the objective to set up an innovative financing mechanism with local banks using public-private partnerships (PPPs). Loans will be provided that are adapted to the renewable energy sub-sector. This is being done in order to promote the development of clean energy, contribute to the reduction of the energy deficit in Mali and to protect the environment. There is a focus on solar energy kits, but similarly this programme can also boost biogas as part of the energy mix.

ANADEB's key ambitions

- *Development of a national programme on biogas*
- *Research and management of various waste materials for biogas*
- *Distribution of 7,000 biogas digesters (2017-2021)*
- *Operationalisation of a bio-energy quality control laboratory.*

There are a number of challenges in the implementation of the regulatory framework:

- *Institutional challenges*: coordination among the mentioned agencies, weak planning and inadequate support to PPPs;
- *economic and financial challenges:* high investment costs versus weak local financial institutions and inadequate financial incentives to attract the private sector;
- *technical challenges:* limited capacity in the sector and lack of access to information
- *social challenges:* lack of awareness raising among consumers on RE opportunities and challenges, and poverty in general of Malian households.

All of these impede affordability, access and use of RE without subsidy schemes.

Use of renewable energy

Teriya Bugu, meaning "the village of friendship" in Bambara, is a community development centre, located 2 hours from Ségou in the direction of San. Its history begins in the seventies, when French citizens Bernard Verspieren and Malian Lamine Samaké developed a model farm and experimental centre on agriculture and renewable energy along the river Bani. Along with the centre, the idea was also to develop a solidarity tourism facility. The objective was to create an example of sustainable development while at the same time supporting the rural community of Korodougou. The centre integrates agriculture, bioenergy development and tourism. It currently occupies 220 ha including the village, and is managed by the *Association d'Entraide pour le Développement Rural* (AEDR).

Teriya Bugu grows various fruit and a wide variety of vegetables and keeps rabbits, chickens and ducks, which are also used in the restaurant. In addition, it keeps horses and donkeys for tourist rides and to work on the land. More than 200 hives produce honey, a product which is highly

Photo by Gazomètre Teriya

appreciated. Production keeps up with the needs of the restaurant with local re-sellers taking care of the rest. Teriya Bugu would consume around 65,000 litres of diesel fuel per year to provide electricity to the centre. In order to reduce this dependency and as part of its renewable energy policy, Teriya Bugu decided in 2006 to start the renewable energy project, producing fuel from the Jatropha *curcas* plant. Also, in collaboration with CIRAD, a research programme was started on Jatropha.

AEDR uses and promotes a mix of renewable energy: biogas, solar panels, solar heating, and a local biofuel industry with the cultivation of Jatropha shrub oilseeds. The electricity, produced by two (25 kW and 33kW) bi-fuel motors, supplies the independent local grid of the centre (including the hotel, school, clinic, welding shop, etc.) and the village where the employees live (500 people). The Jatropha cake is used in a Transpaille® biogas reactor with a capacity of 50 m^3 producing 12,000 m^3/year of biogas; this supplies the centre kitchen. Biogas thus obtained is stored in two flexible containers that each hold 50m^3 of biogas. These are pressurised with sandbags and supply several gas stoves at Teriya Bugu. Solar energy is used for water heaters and for irrigation water from the Bani River, saving over 7,500 litres of diesel per year. Teriya Bugu further promotes a garbage collection system in the village. The waste treatment plant adds to the production of biogas. Composting at the plant also produces digestate (7 tons/year), which aids in development. Tests are carried out on these organic fertilisers.

The activities of Teriya Bugu support in total 7,000 people in the community of Korodougou. The bio-energy mix (electricity and biogas) is enough for its needs, thus saving more than 35,000 litres of diesel per year, *i.e.* around 1,400 Euros/month.

WABEF and Teriya Bugu

AEDR-Teriya Bugu is a promotional centre for RE and especially for bioenergy. As such it is an ideal partner to promote anaerobic digestion of bio-wastes in Mali. For demonstration purposes, the Transpaille® unit was rehabilitated to allow the anaerobic digestion of Jatropha cakes. In order to make the centre fully operational for demonstration purposes, instruments to better monitor the biogas plant were put in place at an on-site laboratory. This allowed for the assessment of the pH, dry matter and volatile solid composition of organic residues and their biogas potential. In parallel, an educational exhibition was developed to inform the visitor. Panels explain the equipment seen, its operation and its integration in the site, and this is very much appreciated by the visitors and trainees.

Closing the loop of the biogas value chain has been done by using the biogas directly for cooking and the digested jatropha cakes as a fertiliser for the crops. Jatropha by-products (fruit shells and cakes from pressing) are poorly valued in general. The raw and processed Jatropha cakes were analysed and their potential agronomic value assessed in terms of:

(i) fertiliser: available nutrients

(ii) soil conditioner impact on physical and biological properties of the soils
(iii) safety: presence of toxins and heavy metals.

The raw Jatropha cake and the digested Jatropha cake have high nitrogen mineralisation potential, and despite a high presence of phorbol esters toxins may be considered as organic fertilisers. Experiments at Teriya Bugu showed no presence of these toxins in fruits and cereals after fertilisation with Jatropha cake, while the yield of tomatoes improved considerably (from 22 t/ha to 31 t/ha, Traoré, Kamaté et al, 2015). In Mali, there is no standard yet for the use of Jatropha fertiliser, but AEDR is working on this with ANADEB.

In addition, WABEF analysed the business of the centre. This exercise provided insight into the social business of biogas, highlighting the need to look at various segments and to combine mixes of inputs and outputs. Since the rehabilitation of the bio-digesters, Teriya Bugu no longer lacks biogas to meet its cooking needs for the hotel. This results in savings on hotel costs and also an increase in the purchase price of seeds of Jatropha to producers (100 FCFA / kg instead of 75 FCFA of Jatropha seed). Teriya Bugu is now able to generate sufficient biogas and fertiliser for its needs.

The 55 cooperatives that Teriya Bugu works with are involved and informed about the process of valorisation of Jatropha cake and also of the waste. Teriya Bugu is planning now to further increase its production of RE, serving the village in biogas for cooking purposes and producing electricity for the community.

Teriya Bugu is one of the pioneers of renewable energy in Mali, with more than 30 years of experience. Together with other experiences, like that of SNV and AVSF, who are running programmes on developing family biogas in Mali, the community approach serves as a model for rural community development. Mini grids using mixes of renewable energy in villages that have sufficient raw material available are an inspiration.

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Centre Songhai: Integrated development of renewable energy in Benin

Justin Lekoto
Jean-Michel Médoc

Centre Songhai in Porto-Novo in Benin is an innovative organisation for integrated development that puts human capital and bio-energy development at the centre of its activities. Currently, the Songhai model has been replicated in Benin and Nigeria and in 15 other African countries, with the support of various donors including UNDP, Songhai was recognised as a Regional Centre of Excellence for Africa by the United Nations in 2008.

Songhai was created in October 1985, borrowing its name from a powerful and flourishing West African empire of the fifteenth century. The idea of the creation of Songhai Centre came from Father Godfrey Nzamujo, who together with others who shared his vision of giving Africa back its dignity. Supported by the government, the project at Ouando (a neighbourhood of Porto-Novo) was started on an acre of land specifically targeting African youth. Songhai Regional Centre in Ouando now covers more than 22 hectares of land and is mainly used as the organisation's headquarters and as an experimental site.

Songhai is a unique integrated development programme, designed to radically address unemployment and food insecurity associated with poverty. It also addresses environmental management. It is not simply a typical model

Participants of the Regional School in Songhai, Benin. Photo by René van Veenhuizen

of training or technology transfer, but also innovates technologies and builds capacities by forming a critical mass of young people to produce *MORE and BETTER with LESS*.

Songhai's innovative strategy consists of four basic components:

- a technology park where new ideas and techniques are developed
- an industrial park where techniques and ideas are transformed into enterprises
- an incubation centre for building skills and providing training
- a service centre.

Renewable energy in Benin

The production and use of energy are determining factors for the socio-economic development of Africa and Benin in particular. The New Partnership for Africa's Development (NEPAD) stipulated that in order to fight poverty and achieve the targets set in the Sustainable Development Goals, each African community should grow its energy production and consumption by at least 7%, to achieve 6% growth in the agricultural sector and 8% in economic growth. This requires integrated, broad and inclusive development, enabling communities to have access to this means of development. In terms of access to energy, access to quality agricultural soils and fertilisers is essential to meet the challenges of

Potential of renewable biomass energy

The annual biomass production capacity in Benin is estimated at 1003 MW, based on the availability of 3.3 million tons of agricultural residues. This biomass pool is in principle enough to satisfy the national demand for electricity. It includes:

- *Residues from agricultural production: mainly cotton, sorghum, millet, rice and maize. Statistics show that Benin has relatively large quantities of residues at the national level which, when recovered, will provide around 4,356 GWh of electricity*
- *Livestock wastes that can be collected for the production of biogas; according to information received from the Department of Livestock, to use 80%. But the animals needs to be housed. Statistics show there are 1,876,800 cattle, 341,700 pigs and 2,229,700 small ruminants*
- *Agrifood processing industries release large quantities of waste (shells and cake of cotton, palm or coconut seeds, and residues of pineapple and mango etc.) and constitute genuine energetic potential. Timber-processing residues in the form of sawdust, chips, etc. can be added to this*
- *Household waste is generated in urban areas in significant quantities and its valorisation could be envisaged for the development of capacities to produce electrical energy to be injected into the distribution network. For example, the City of Cotonou generates more than 700 tons of garbage per day. This potential could allow the installation of a power plant with a capacity of 5 MW.*

adapting food systems to climate change and food security.

In Benin under a scenario of strong economic growth, total electricity demand would be 4,116 GWh in 2025 with an installed power requirement of 635 MW. With the current capacity of 160 MW managed by the Benin Electric Power Company (SBEE) and the Benin Electricity Community (CEB), Benin has to import nearly 80% of the electricity it consumes from neighbouring countries (Ghana, Nigeria and Côte d'Ivoire). In 2025, Benin targets an energy mix comprising 24.6% of renewable energy.

The Government of Benin supports the enhancement of renewable energy and the use of bio-wastes, through research and financing, including through:

- SREP: A large-scale renewable energy development program in low-income countries
- The second Compact of the Millennium Challenge Account, signed on September 9, 2015 in Washington, which aims at the reconstruction of the energy sector and includes production, distribution, institutional reform and decentralized energy components. This agreement is worth about $ 411 million
- Financing of private developers to set up infrastructure for the production of electricity from renewable energy sources
- Financing through its own funds in conjunction with concessional loans from development banks.

WABEF and the Songhai Centre

In order to meet these challenges, Songhai is promoting an integrated system that includes the recycling and upgrading of organic residues from agricultural production (animal waste, crop residues, and processing effluents). New ideas and techniques are disseminated in the Technological Park of Songhai.

Within the framework of the WABEF project, extension and teaching materials have been developed and made available to inform and educate the general public on biogas production technology. The park receives more than 450 visitors each week on average. These are potential future agricultural entrepreneurs, specialized in the field of renewable energies. On average, there are 40 young people who specialise in biogas per semester. The framework also welcomes 5 to 10 students from universities and elsewhere for their research work on biogas production and recovery technology.

Currently, the Songhai Centre in Porto-Novo produces an average of 1,300 m^3 of gas per month, supplying two generators with a total power capacity of 75 kW for the production of electricity. This off-grid electricity production satisfies 10% of the energy needs of the Centre's three production sectors at an average price of 111 FCFA/kWh. The digestate (11 tons/week), is used to fertilise 5 hectares of crops (horticulture and fruit production) and 2 hectares of fish ponds, producing enough for the restaurant and allowing to avoid the use of 1.4 tons of chemical fertiliser per year. The synergies created at Songhai allow organic products and residues to be sources and sinks and generating the energy necessary for integrated and inclusive socio-economic growth in rural and urban areas. Supported by WABEF, Songhai has analysed the costs and benefits of the biogas system and has taken the measures suggested to make it more efficient.

Gbéko town is located about 30 kilometers from Porto-Novo, and has 20,000 inhabitants. Like all rural areas in Africa, Gbeko's economy is characterised by non-competitive, unprofitable and non-attractive subsistence agriculture for young people. This leads to a massive rural exodus of young people from the region. The rural electrification project is supported by Ministry of Mines, Energy and Water. It consists of developing decentralised renewable energy as a central lever for transformation and rural development, creating a synergy between agricultural production and energy.

Energy will come from biomass issued from forest products, animal waste and agricultural by-products and residues. Green energy (biogas, gas) and solar energy will be produced not in a centralised but rather a distributed way. The challenge will be to connect them and redistribute the energy through a smart grid. Thus, each zone and each family is both producing and consuming energy.

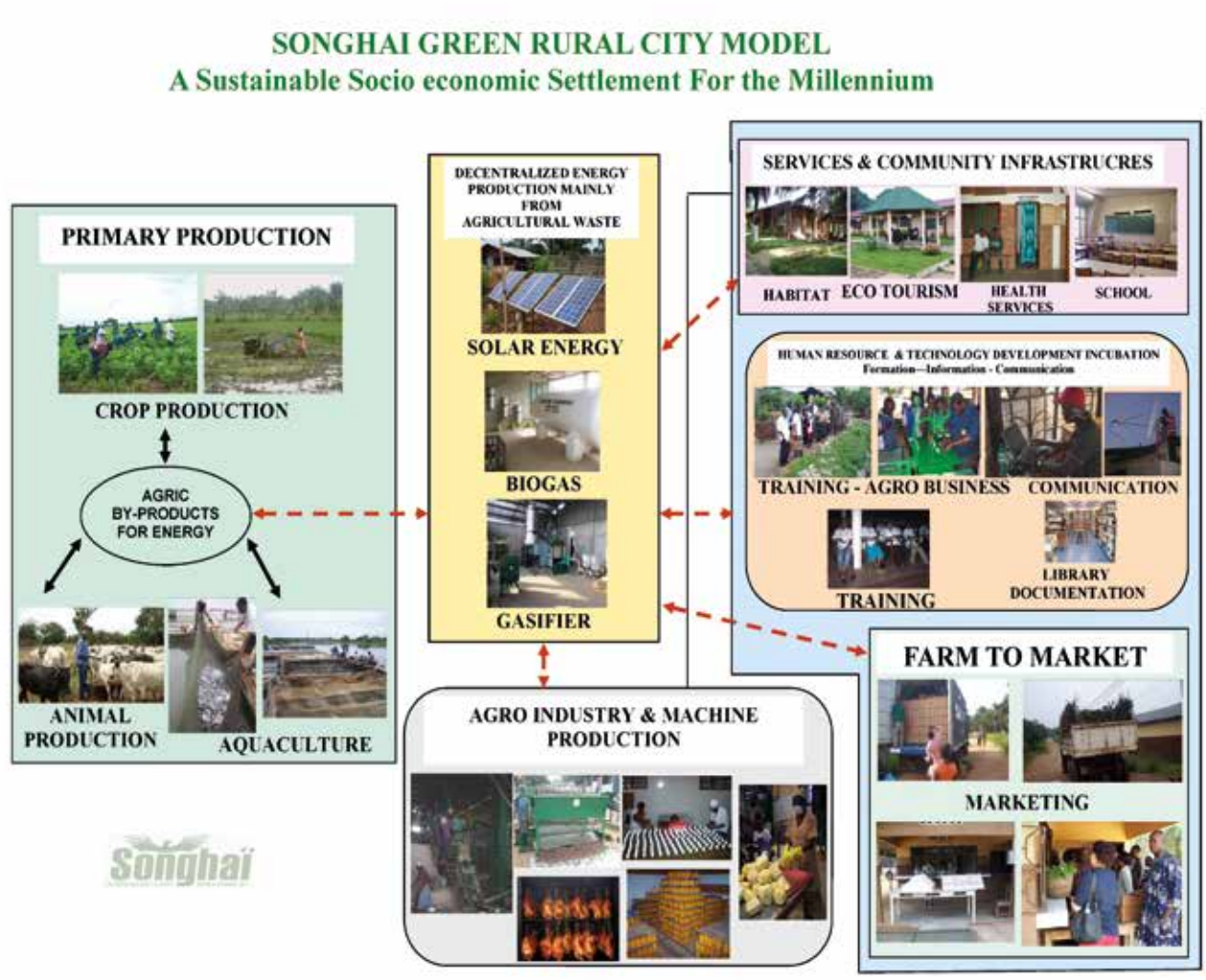
It will be used for various agricultural and para-agricultural activities such as year-round irrigation, processing and conservation of agri-food products, transport to create an internal market and exchange networks with other regions.

- *Bringing energy to the 20,000 inhabitants of the isolated district of Gbeko, and around the Songhai Centres*
- *Starting similar pilots in other isolated rural areas and other Songhai centers*
- *Transferring skills to local Songhai partners and creating an enabling environment.*

The advantages are increased and diversified production and related technological activities along the value chain. This aims to create opportunities and increase purchasing power, savings and investment capacity of communities. The project will be further extended to Gbéko, Parakou, Savalou, Kinwedji, and Ikemon, with Porto Novo as the centre of research, development and training.

Related activities of Songhai

In partnership with SNV Benin, Songhai has developed and installed nearly 200 household bio-digesters, valorising agricultural residues, and supporting local power generation for SMEs. Songhai succeeded in increasing or even doubling the conventional production of biogas with the introduction of Efficient Microorganisms. SNV Benin, Songhaï, the Directorate General of Energy, Ministry of Agriculture and ABERME, are involved in developing further use of biogas in Benin. A National Biogas Programme is being developed, as in Ghana.



Songhai has furthermore developed a gasifier that supplies co-generators of 60 kW for the production of electricity for fruit-juice processing plants and heat for drying vegetables, fruit or pellets for fish. This *Singaz* product is derived from valorisation of tree-pruning residues, palm kernel shells, coconut shells, corn cobs after ginning, etc. The biochar produced after the gasification is currently valued and developed as soil conditioner, fertiliser and for the purification of the waters used in fish culture. Photovoltaic solar energy is also developed and used to enable the operation of the crop irrigation network and lighting.

Integrated development, Songhai's ambitions

The Songhai Centre is recognised by United Nations agencies as a Centre of Excellence for the promotion of entrepreneurship in Africa. The Songhai model is a viable initiative for further development and acknowledged as such by the Benin Government. Songhai is facilitating the Benin Renewable Energy Platform with the Government.

The integrated project "Songhai Energy" aims to produce, and to stimulate the production of, renewable energy. The aim is not only to meet the energy needs of the various Songhai Centres in Benin, but to work in the same way with and for the surrounding communities, particularly those located in rural areas. This will also help to reduce the rural exodus and impact the increase of urban slum, with a positive impact on their development. A good example of this decentralised energy development or micro-grids is the Songhai experimental rural electrification project in Gbéko, which is a key element in the sustainable socio-economic transformation of rural areas into green cities in Benin.

Recommendations

Based on Songhai 's (including WABEF's) experience and work, the following recommendations are given:

1. Enhance information on total wastes generated and biomass energy value and the potential in Benin
2. Enhance information on available technologies
3. Increase access to finance and stimulate entrepreneurship
4. Further establishment and implementation of a National Biogas Programme.

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WABEF Support to Renewable Energy Development in Senegal

Moussa Ba,
Jean-Michel Médoc

Senegal, like many other countries on the planet and in the West African sub-region, is investing in renewable energies (RE) in view of the high dependence on oil and gas that make economic development of the country vulnerable. Thus, the Senegalese authorities are developing a policy based on the search for alternative solutions following the development of RE and diversification of sources of production.

To this end, the National Agency for Renewable Energies (ANER) was created to promote and develop RE: solar, wind, hydro and biomass. The objective of the government through its agency is to achieve an energy mix with 20% RE in 2017 including hydroelectricity. Solar energy plays a major role among these ambitions. In 2016 two solar power plants with a total capacity of 42 MW were connected to the national electricity grid, which, in January 2017, contributed to a 10% decrease in the price of the domestic KWh (the most expensive in the region). Four other solar power plants are under construction and their delivery is expected end of 2017 for a total capacity of 84.5 MW. This would increase the contribution of RE (solar + hydroelectricity) to 20% of the energy mix by end 2017.

Biomass is no less important as the development of biogas production begins. Indeed, the government's National Domestic Biogas Programme in Senegal (PNB-SN) aims to install 10 thousand domestic biodigesters by 2019, with a capacity of 8-12 m³, for 9500 rural households across the country. There will also be biodigesters with a capacity of less than 18 m³ for 500 school canteens and *Daaras (Koranic Schools)*. A much higher-scale production capacity involves two private and one NGO in agro-industries (slaughter houses), and the National Office of Sanitation of Senegal, who is recycling sewage sludge issuing from the treatment of municipal waste water and faecal sludge.

WABEF and Senegal

In Senegal, many stakeholders are involved in the development of biogas. In addition to the Ministry of Energy and Renewable Energy Development, most of the ministries comprising the Senegalese Government are involved, along with their agencies, national programs, local authorities, inter-municipal groups, the Consular Chambers, etc. A strong synergy has been developed with PNB-SN, initiated by WABEF as a synergy between European-funded projects.

Biogas from slaughter houses

The Dakar abattoir recycles its waste (50 tons of a mixture of stomach contents, dung, blood and washing water per day) in a Thecogas biogas plant with a capacity of 4,000 m³, producing 1,000 m³ of biogas per day. This biogas generates 800 kWh per day and 1,700 MW of heat annually, covering 50% of the power and all the hot water needs of the abattoir. In 2015, the cost price of the kWh was 81 FCFA and it was sold at 101 FCFA. Daily, the equivalent of 80% of the intake is evacuated as a bioslurry. A litre of bioslurry is sold at 200 FCFA for volumes less than 1 m³. Beyond this, the price goes down to 50 FCFA/litre and even 7.5 FCFA/litre if all the daily production is bought (between 30 and 50 m³). Thecogas and the Biogas National Program are engaged in a standardisation process for bioslurry to provide farmers with a satisfactory cost/efficiency ratio fertiliser.

The potential exists for up-scaling of this technology at the Dakar slaughterhouse. To date, only one quarter of the wastes produced daily are digested. This reduces the daily power consumption from 2600 kWh to 1800 kWh. Treating all the wastes produced would allow the abattoir to further reduce its consumption by 1250 kWh per day. Even better, the slaughterhouse has an exclusive purchase contract at a preferential tariff of electricity, the biogas plant having exclusive access to the waste source. The Senegal Slaughterhouses Management Company (SOGAS) runs eight abattoirs around the country where this model could be developed.

In Saint-Louis, at a more modest scale, a unit of five floating dome digesters with a capacity of 10 m³ each is installed in this slaughterhouse thanks to collaboration between the NGO Le Partenariat and SOGAS. The unit produces 20 m³ of biogas per day sold to the surrounding households at the rate of 200 FCFA per m³ while the bioslurry is sold to market gardeners in the locality.

As a first step, a consultative workshop with stakeholders, school canteens and Koranic schools on sustainable development of a biogas market in Senegal was organized in partnership with PNB-SN and with the support of the Embassy of France in Senegal in 2015. Collectively WABEF and PNB-SN designed inventories of the development situation of industrial and domestic biogas in Senegal. This workshop

Thecogas Anaerobic Lagoon at the Dakar Abattoir. Photo: Léonce Sessou

To reach the national biogas (available methane) potential and the fertilising value, it is paramount to quantify the bio-wastes available. A methodological framework was developed for collecting and linking all the basic references needed to calculate the deposit and its potentialities. These included livestock, cultivated areas per district, ratios of production for manure and residual biomass, duration of production cycles, number of cycles per year to calculate the gross deposits, plus the time at barn for animals to reach the required deposits, and finally to reach the available deposit of bio-wastes. The valorisation or use ratios were obtained according to the practices of farmers from group interviews. This approach to the acquisition of the deposit has been illustrated by the quantification of organic residues from agricultural crops and livestock in Senegal.

engaged the actors in the path of the development of biogas in order to avoid sectoral approaches and allow a shared and integrated vision.

In addition, a research programme funded by PNB-SN and implemented by Institut Sénégalais de Recherches Agricoles (ISRA) and CIRAD began early 2016 and will run for two years. This research will acquire agronomic, energetic (Biochemical Methane Potential) and environmental (metallic and organic contaminants) references on bio-wastes that may be digested and on the bioslurry. To allow this research on the biogas potential of local bio-wastes, an automatic biogas (methane) potential test system deployed by CIRAD in the International Joint Lab "Ecological intensification of agricultural soils in Western Africa" at Centre ISRA/IRD of Bel Air in Dakar, Senegal. This facility, equipped with 15 parallel test lines, is of regional interest and the first local results are now available.

To meet the decentralised energy needs for populations and industries, as well as fertilisers, identifying the available bio-waste deposits for methanisation must be done. In Sénégal, bovine manure represents a potential deposit of 1,691,135 tons of DM/year. The importance of the quantities emitted and the control of this total gross production at 50% are the two important criteria which have guided the choice of the PNB-SN to consider this resource as the main substrate for the operation of domestic biodigesters. However, due to its irregular distribution, the high demand for substrates for operating year-round and the distribution of these devices, bovine manure is insufficient. In the second phase of its program development, the PNB of Sénégal has embarked on a multi-stakeholder partnership. ISRA and CIRAD will research alternative substrates for bovine manure, to ensure efficient and continuous use of household biodigesters subsidised by the programme.

Lessons learned

There is a need for more appropriate regulatory frameworks that provide incentives to various uses of biogas, and that engage local authorities. The level of maturity of biogas technologies and the associated technologies in the waste to energy and agriculture chain must be improved through the development of normative frameworks. In addition, relevant authorities, decision makers and practitioners need to have access to proper information and operational tools for the design of their project or business. Access to private and public funding's need to be enhanced and more specific.
And this legislation, information and supports, needs to be adapted to, and available at, the sector and level of operation. There is a need to properly monitor technologies and policies and the level of maturity of innovation, raise awareness, inform and train while changing mind and behaviour.

In order to accompany the development of the sector, the conditions for setting up an institutional framework conducive to decompartmentalizing and developing synergy between institutions, sectors of the economy, civil society, practitioners and private organisations, should be brought together.

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Poo Power in Ghana's Biggest Slum

Raymond Okrofu Ategbi

In many Ghanaian schools ash is used to wash your hands after using the toilet; a lot easier to find and the same amount of cleanliness according to the World Health Organisation. Photo by Safi Sana / Facebook

According to ECOWAS this is the first grid-connected biogas plant in Ghana and the second in West Africa. Located in the city of Ashaiman, Ghana's biggest slum community (population about 300,000) where sanitation facilities are non-existent or dilapidated and poorly managed, the Poo Power plant built by Safi Sana Ghana Limited is a novelty. It also offers great relief in terms of sanitation and the supply of power to the grid to serve the people in the community.

With the rapid growth of population in communities like Ashaiman, demand for sanitation facilities is high and the situation deteriorating. Mostly sanitation facilities have never existed. Where they do exist, their condition and management are very poor. The Safi Sana sanitation model intervenes along the entire sanitation value chain, ending up with the treatment that generates two main outputs, organic fertiliser and electricity. The article details the Safi Sana model, the process of biogas to electricity, the impact of the project in the Ashaiman community as well as the partners involved in the project.

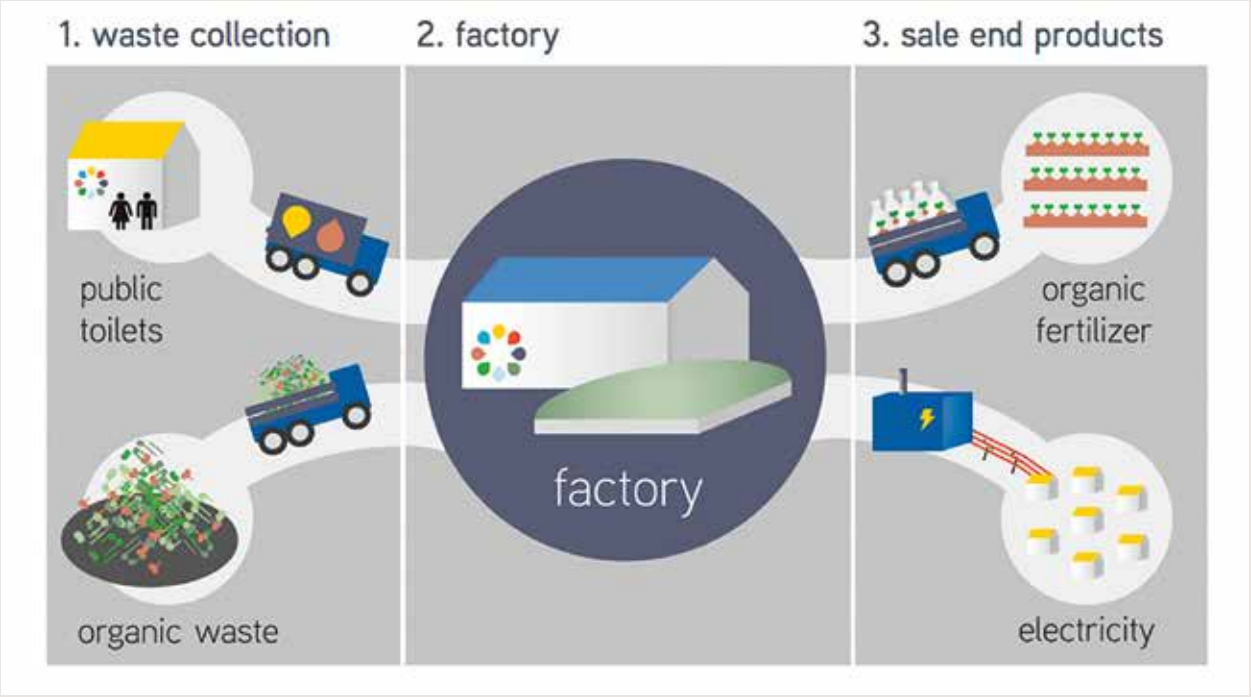
The Safi Sana model

The Safi Sana model is based on seeing waste as a resource. Faecal and organic waste is collected from urban slum communities, for example from toilet blocks, restaurants, markets and slaughterhouses and used as input in our factory. Here waste is treated in a biogas digester to produce biogas, organic fertiliser and irrigation water. The biogas is subsequently used to produce electricity.

Communal toilet blocks to serve about 200-300 people are built in the areas of the slum where they are most needed. Management of the blocks is franchised to local NGOs or individuals in the locality who charge subsidised user fees. This ensures communal ownership and sustainability. Safi Sana company trained a team of cesspit truck owners, forming a Toilet Services Network. They are supported to transport the toilet waste from the nooks and crannies of the community to the treatment site. Travel time and cost is reduced as the treatment plant is located within the community.

Safi Sana also collects solid organic waste from the market, local restaurants and slaughter houses. The waste collection activities cover about 20 km radius around the factory. Young men and women have been recruited, trained and supported financially to move round the community with tricycles to designated collection centres, markets and the slaughter houses. In some cases existing waste collection companies are used to transport waste to the site. Market women and the slaughter house operators have been trained to segregate their waste according to the various fractions. The biggest challenge so far has been getting clean waste to feed the plant.

The local municipal assembly is also involved in educating the inhabitants and promoting sound sanitation practices through a committee of opinion leaders and leaders of various associations in the community. The aim is to support the local population through a market-driven approach. Safi



Sana Company works together with national and local governments, NGOs and the private sector. Our 'tri-partite' philosophy combines government support, social and sustainable values and a commercial business plan. Together we work to establish a stable and financially sound company.

The process

Through a process of fermentation, the organic waste goes through four biological and chemical stages to generate the biogas. These stages are: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Anaerobic digestion (AD) is a process dependent on microbiological activities in the absence of oxygen. This microbiological process exists naturally in such environments as swamps and the stomachs of ruminants. Using an engineered approach and controlled design, the anaerobic digestion process is applied to process organic biodegradable matter in a reinforced PVC airproof reactor tank to generate the biogas. The process ends up

Different groups of microorganisms play different roles in the process. The hydrolysis phase involves the breaking down of the complex biomass into simple molecules using enzymes and water to separate the chemical bonds between the compounds. In the next stage, acidogenesis, bacteria convert the biomass of simple sugars into short fatty acids. It is this stage that alcohol, hydrogen and carbon dioxide are produced. In the third phase of the process, acetogenesis, acetate is generated from energy sources with the end-products carbon dioxide and hydrogen. For proper and effective anaerobic digestion and methane production, this phase is very important. The final stage in the digestion process, methanogenesis, is when methane production occurs. The bacteria that produce methane are so unique that scientists have categorised them into a new evolutionary domain referred to as Archaea. Biogas is the end-product of the digestion process. Though a mixture of many gases, biogas is predominantly made up of two, methane and carbon dioxide, which account for 80-90% of the mix. Hydrogen sulphide and ammonia gases are found in very small proportions.

New good and promising results for fertiliser on plant test using faecal matter as input. Photo by Safi Sana / Facebook

Safi Sana site cleaning team Photo by Safi Sana / Facebook

with two main outputs: energy-rich biogas and a nutritious digestate which can be used as organic fertiliser.

This biogas generated in the anaerobic reactor is connected to a power generation unit, a combined heat and power plant with an installed capacity of 100KWh of electricity. This electrical power is fed into the grid in Ashaiman.

Safi Sana signed a power purchase agreement with the Electricity Company of Ghana so the electricity which is fed in to the national grid is paid for by the utility provider. Being the first of its kind in the country, there were some initial challenges. Negotiating the power purchase agreement took close to a year, with clauses on legal and technical issues generating disagreements, plus technical challenges on linking to the grid.

Impact

By offering an integrated waste-as-resource programme, Saf Sana achieves two important results:

- First, the means to maintain the service for many years: waste is collected from the community and treated, with the end-product ploughed back into the community as affordable organic fertiliser. Also, the project has a nursery where high quality seedlings are raised using the organic fertiliser and treated waste water. Including the sale of these seedlings to local farmers at very affordable prices, jobs are created all along the entire chain.
- Secondly, a long-term perspective is created for the local inhabitants. The estimated effects of the new plant in Ashaiman are:
  - 13 tons of toilet waste treated daily and not pumped into the sea or nearby bush
  - 15 tons of solid organic waste recycled daily and not left to feed rodents or block sewers
  - 40,000 people will have access to improved toilets
  - Electricity generation sufficient to serve over 3,000 families daily
  - 720,000 m2 farmland gains access to vital nutrients using the organic fertiliser.
  - 25 people directly employed and many more supported as suppliers or partners

For more details go to www.safisana.org/en

Photo by Jean Michel Médoc

Climate change and migration to cities continue to put pressure on existing infrastructure. The Safi Sana end products -biogas, organic fertiliser and irrigation water – add to water productivity, food security and climate resilience. They also deliver direct and indirect health and economic benefits to 125.000 slum dwellers in Ashaiman.

Project partners

For the first project in Ashaiman, partners include: the African Development Bank; RVO Netherlands; Via Water; Ashaiman Municipal Assembly (provided a 5 acre piece of land); WASTE and WereldWaterNet; Royal Haskoning DHV; IFDC; Wageningen University; and Aqua for All. The ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) carried out a survey that revealed Faso Biogas in Burkina Faso is the first grid-connected biogas plant in West Africa and Safi Sana is the second.
www.ecowrex.org/news/west-africas-first-grid-connected-biogas-plant-burkina-faso.

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Biogas is Business – Even at household scale

Harry Oppenoorth
Jean Marc Sika
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Africa Biogas Partnership Programme in Moshi, Tanzania. Photo by Hivos

Few people know what a biodigester is and what it can do. In the western world, it is often seen as a huge device where waste is somehow managed. In developing countries, few people have an image at all. This article describes how HIVOS and SNV (ref.) established a biogas sector in Africa, overcoming constraints to commercial viability, and demonstrating that biogas is not only a solution to harmful and inefficient wood-fuel cooking, but also an alternative to the expensive chemical fertiliser-based farming:, in fact it is a perfect fit for mixed farming and in general a life-changer.

Benefits of a biodigester

A six-cubic meter biodigester will work perfectly when fed daily some fifty kilograms of fresh manure mixed with fifty litres of water. It will produce two cubic meters of biogas daily, enough to cater for all the daily cooking needs and provision of light for a household. Women and children never have to go out to look for firewood anymore, and save a lot of time, or money in those areas where there is no free firewood to gather anymore. Cooking is convenient and clean and the kitchen remains free of smoke. Annually two to three tons of firewood are saved

But what's more, the digested manure, bio-slurry (the digestate), is a potent organic fertiliser. Its nutrients are easier to assimilate by the crops and give better crop results than untreated farmyard manure. When well applied, production increase in most crops is hardly ever below 20% and more often a lot more. It is rich in elements and minerals, can be applied in many ways, restores soil structure and organic matter content and is even a pest repellent. It is applied to kitchen gardens, staple and cash crops, is used for fish rearing and poultry and even as an animal feed supplement. This size of biodigester can produce enough bio-slurry for intensive year-round farming on 1-1.5 hectares of land.

The gas and the bio-slurry are at the root of the business case for the household: time and money savings on the fuel side, money saving on chemical fertilisers, additional production and income from the agricultural activities on the bio-slurry side. It certainly makes sense to invest in a biodigester. Within two years the digester has paid itself back and it will last a lifetime. The benefits are clear.

The 1000 Cookies Lady in Tanzania

Mrs Khadija Maghembe in Western Tanzania complained she frequently did not have enough gas from the digester. Her digester however was a thirteen-cubic meter one, that should produce enough gas for cooking all meals of two big families. When asked, she explained she produced a thousand cookies daily, which she sold in the market, earning something like USD 15 from that every day.

The Biodigester market development programmes

In 2009 HIVOS and SNV started a programme to scale up biodigester dissemination among small scale farmers in six countries in Africa (Burkina Faso, Ethiopia, Kenya, Rwanda, Tanzania and Uganda). This was informed by success stories from China and India, following the pilot national biodigester programme in Nepal SNV started in the eighties. That became a huge success, reaching levels of around 270,000 digesters delivered by the programme with an almost equal amount built independently, up to today. It was soon followed by programmes in Vietnam and Cambodia. The secret of this success is the market-based approach model. If something doesn't work in the market, large scale dissemination will never be reached. The market-based approach involves private and public sector partnerships to enable scale-up and adoption.

The same approach was up-scaled by HIVOS and SNV in Africa (the Africa Biogas Partnership Programme - ABPP) and Indonesia (the Indonesia Domestic Biogas Programme - BIRU): this was called the multiple-actor market and sector development approach. At the core of this approach are the masons and biodigester construction enterprises on the supply side and farm households on the demand side. The ABPP and BIRU programmes train masons and support them to become small contractors, to create the supply. At the same time, intensive promotion campaigns and marketing activities, initially by the programmes and partner organisations, target the high potential farmer sectors.

Slowly the numbers of installed digesters in Africa began to grow. The digesters are however not cheap. The families are faced with the choice to buy another heifer, or two, or to buy a biodigester. The first few years this is mitigated by a subsidy, but the cash outlay is still considerable. After the first stream of early adopters starts drying out and subsidies are withdrawn in some countries, the growth starts slowing down.

The crispy biogas-chip business in Indonesia

It has been five years since Mugiyati first started her chips business in Getasan, Central Java. She now sells her chips at nearby kiosks. "It's doing pretty good. The money adds to my income," she said. "I used to run this business only during dry seasons. It takes a long time to dry the chips on a rainy day. Besides, I used to buy LPG to cook them. So, I actually suffered financial loss." Using home biogas has helped push down production cost. "I used to spend Rp 60,000 (USD 6) per month on LPG. But now, the fuel cost is close to none because I have been using biogas."

According to Mugiyati, owning a home biogas digester opens up a lot of business opportunities. "If it is possible for you to start one with the help of biogas, do it. You will get double the advantage. Not only can you save fuel, you can also get some extra income," she said firmly.

Affordability and credit

Affordability is an issue, and so is the reputation of the technology. A lot of effort has been put into mobilising credit for biodigester purchase to address the affordability issue, but with mixed results. Initially, credit institutions were

Africa Biogas Partnership Programme in Moshi, Tanzania. Photo by Hivos

reluctant to engage, not well aware of the technology, and there were certainly stories floating around about failing digesters. Functionality of the digesters became top priority and quality control had to be intensified hand-in-hand with creating more awareness about the importance of quality and reputation among the biodigester construction enterprises. Today the companies are rated according to their performance and the number of issues with their plants and the percentage of non-functioning plants is below 5% in most countries in Africa.

Confidence in the technology is improving, both with farmers and with the credit institutions. But still credit availability is an issue in many areas. If credit were readily available, demand would easily double. The next bottleneck turned out to be limited capital availability. Second-tier capital providers can solve this issue, but their requirements are not easily fulfilled by all local credit institutions. Biodigester businesses are often considered too small and also they cannot often come up with the required securities. Mitigation of the risk of default on payments becomes important. Here the programme comes in and organises close follow-up of the loans and the construction company, to secure proper delivery of the digester and timely loan repayment. Eventually the financial institutions start seeing there is business in the biodigester sector.

Reputation and Marketing

The reputation of the technology is improving. The companies are improving, some even growing fast, producing a hundred digesters per quarter or more. We have learned that the best marketing strategy (not the only one) is to tie together a famers' organisation like a cooperative, the credit organisation (they often have relations to or are even owned by them), one or more biodigester construction enterprises, and a quality control and repair service company. If these four start to know each other well and trust is built, demand can grow fast in that cluster. We call this the biodigester marketing hub. The cooperative (supported by the programme) starts to promote biodigesters amongst the members. Those interested can obtain credit and the supplier is there, ready to start building. Independent verification by a call centre confirms if credits are given, if digesters are completed and checks if they are working, if issues are addressed and if after-sales services are provided. It flags when quality inspection is to take place and when issues need to be addressed.

Uganda - Mugabe's banana farming

Mr. and Mrs. Mugabe are residents of Katinda village in Mbarara District. The couple had lost hope in banana farming due to poor yield. This was attributed to the rocky and unproductive nature of the place. On learning about the biogas digester and the advantages it has on improvement of soil fertility (thanks to bio-slurry generated from it), they went ahead to establish one. When the biogas plant started producing slurry, they applied it on their farm. They first experimented with the growing of vegetables like carrots, spinach and collards. The results were above their expectations! With that amazing experience, they went ahead to establish a banana garden with bio-slurry. The bananas were so healthy that they decided to expand into a larger area of the rocky farm. Today, they use bio-slurry for composting and applying on other crops like pumpkins, ground nuts and beans.

Photo by HIVOS

Although the costs of this service are only a very small part of the total cost of the digester, it is however a vital service. To make it work, it is essential to assure compliance by all parties. Not all farmers are organised, so not all potential clients are engaged with a value-chain organisation. For those who are not, the ranking of biogas construction enterprises at least shows which companies work in which area and how their performance is rated. The farmer can then choose. Once construction has started, follow-ups to households are conducted by call centres to see if everything is running smoothly and to answer any questions. The farmers sense a certain protection if they know they can turn to the programme if something fails.

From market creation to market establishment

In Africa, the biodigester market has not reached the market establishment phase yet. But what is promising is that some new companies have now entered the market with ready-made plastic digesters. Here the digester can be the collateral for a loan, at least partly, because it can be removed.

We feel young again - Kenya

Just over a year ago, there was a drastic change in the Githiri household thanks to the installation of their biodigester. "We feel young again," says a beaming Susan when asked how the biodigester has changed her life. "I don't have chest problems anymore and I don't have to wake up early anymore to go and fetch firewood. My health has improved immensely and I feel I a lot more relaxed." For cooking she now uses gas generated from her biodigester. Her days of fetching firewood are long behind her. The slurry, a by-product of the biogas plant, is used as organic fertilizer on their farm. It is full of nutrients and guarantees a rich and robust harvest. Furthermore, the slurry provides a source of income for the Githiris as they can sell the leftover slurry to neighbouring farms. "I have forgotten about buying artificial fertilizer. My harvest has improved tremendously. I used to harvest 10 bags of kale per week and now I am harvesting 25 bags a week," Susan says excitedly. With the bigger harvest, there has also been more income for the Githiri household.

Such companies are also bigger than the contractors and can attract investment and create confidence in the market. The presence of these companies shows that companies and private investors are starting to see opportunities in the biodigester market. Still, few financial institutions or investment funds have as yet ventured into this market.

In six countries in Africa together (Burkina Faso, Ethiopia, Kenya, Rwanda, Tanzania and Uganda) to date more than 70,000 digesters have been deployed since start-up in 2009. It is a large number, more than what was built in the whole of Africa together over the last five decades. There has been a similar experience in Indonesia: 20,000 in seven years. But it is still a very small percentage of the total market potential. Even in Kenya, where market development is the fastest, the market penetration rate is less than five per cent so there is still a huge scope. Slowly, market establishment is consolidating and further growth will materialise.

Shifting roles of the programmes

This differentiated development requires a tailored approach of the programmes. Where at the start the programme was the implementer, gradually programme functions were transferred to partner organisations and the construction companies and the role of the programme shifted to a more supporting one, mobilising missing vital components. Today the role of the programme is becoming more and more facilitating and coordinating among the market players and other sector actors. Credit provision, mason training, bio-slurry extension, business development service provision, quality management, subsidies, inclusion of new players in the market, testing new models, standard development, all together the sector starts shaping.

This is the general line of the market and sector development and what we have learnt. At the same time, every country has its own story. Some governments are very supportive, others indifferent. Some countries have very vibrant dairy sectors where large numbers of digesters were sold, other areas are far away, farms are few and far apart and these zones are not very attractive for a company to engage. In some countries firewood is abundantly available; in others women spend up to 2 days a week gathering firewood for cooking and lighting. Sometimes credit is easily accessible, elsewhere it is totally absent. Droughts and poor harvests, even political unrest are other factors that may interfere because they influence the payment capacity. The human factor programme management is much more effective in some countries than in others. So, there are no general recipes and very few shortcuts. Anyway, the biodigester markets are emerging and growing, but would certainly be helped with a lot more support and investment and more engagement of the sector players.

Urgency

A solution to wood-fuel and charcoal cooking is imperative. In all countries deforestation is rampant and population growth is high. Within twenty-five years twice the population will have to cook with only half of the forest resources remaining and in some countries forests will be practically eliminated. Access to energy is a fashionable theme today. However, by far the most attention goes to electrification. The most pressing energy needs of poor people are cooking and lighting and perhaps also communication. The last two can be resolved through electrification, either through connecting them to the grid or by decentralised off-grid generation. Electric cooking is still very expensive and the mini-grids connected to solar farms, waste gasification, micro hydro schemes or solar home systems generally do not have the capacity to generate sufficient power for cooking. Affordable electric cooking, particularly in the country side is still a mirage. Biogas, for those who have livestock, is by far the best solution for cooking. It is totally clean and substantial energy. Besides, instead of emitting greenhouse gases (like LPG does) it reduces greenhouse gas emissions.

It improves production and generates other activities such as producing food for the market, horticulture product sales, fish and poultry production. It clearly improves food security and income. Kitchens are clean. It modernises the farm and even changes gender relations. Women gain time and often independent income, men start preparing coffee, tea and warming up breakfast.... The biodigester is a life changer.

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Notes

1) Biodigester of the fixed dome type. The same would apply for a nine-cubic meter tubular digester, where the double volume of water is applied for feeding the digester.

Gender Analysis of the Nepal Biogas Programme

Indira Shakya

In Nepal alone 7500 persons die annually from Acute Respiratory Infection (ARI) related diseases, mostly are women and children. Evidence suggests a significant relationship between exposure to Indoor Air Pollution (IAP), like hours near a stove and ARI. It is the poor who rely on the lower grades of fuel and have least access to cleaner technologies. Improved cook stoves enable the reduction of impacts from IAP. The Government of Nepal has therefore emphasised the promotion of improved cookstoves since the 70s, while in 1996 the promotion of biogas technology started. Presently, the government has introduced the "Clean Cooking Solution for All" campaign which concludes in 2022. This article provides some lessons on social aspects, specifically the gender aspects, of biogas technology in Nepal.

Biogas in Nepal

Despite a large hydropower potential of 42 GW, Nepal has a low per capita electricity consumption, averaging 146 kWh/person annually compared to the South Asian average of 517 kWh/person. The current level of household electrification is at 73% with only 30% in rural areas. The primary energy consumption is largely traditional biomass which constitutes 80% of the mix, followed by petroleum (11%), while stand-alone renewable energy resources counts for 2.6%.

The first biogas plant was introduced in 1955, but it was only in 1975 that the government launched a biogas program providing interest-free-loans. With the launching of the Biogas Support Program (BSP), under the Netherlands Development Organisation (SNV) in 1992, further funding and technical support became available for development of the sector. The program aimed to disseminate the technology and develop biogas plants as a mainstream renewable energy solution, while addressing poverty, social exclusion and regional imbalances. It also aimed to stimulate commercialisation and sustainability of the sector. Development and strengthening of innovative funding solutions and an integrated approach combining biogas with water and sanitation were included as well. The principal stakeholders, Alternate Energy Promotion Centre (AEPC), Biogas Sector Partnership Nepal (BSP-Nepal) and Nepal Biogas Promotion Association (NBPA), remain responsible for policy formulation, management and monitoring and installation respectively. The program operates as a successful public-private model.

Based on this model, biogas technology presents an option to enhance sustainable energy use in developing nations particularly in the rural context. However, there is also huge potential for its use for managing waste in the urban areas also. In the case of Nepal biogas has been promoted largely for cooking and sometimes for lighting. Its promotion for other uses (like electricity) in urban settings has yet to take place, including in Nepal.

Gender aspects of biogas

Biogas is women friendly, reducing the workload of collecting fodder and fuelwood, cooking and maintaining a clean environment inside and outside the house, all women's tasks according to social and cultural norms. Women's work is not valued the same as that of men, but biogas has played a role in changing the lives of women in rural areas. These changes have been brought about by deliberate actions of the biogas program, which have benefited both men and women:

- Encouraging women's participation in training for supervisors, masons and management of installation companies, through women-friendly event management
- Provision of additional installation subsidies to single women, the poor and remote areas
- Enhancing income through sensitisation on use of bio-slurry in vegetable farming, fish- and pig raising
- Financial education and access to finance through co-operatives.

Social benefits

Biogas being a clean fuel, the primary benefit is to health, due to the reduced indoor smoke and air pollution. The resulting smoke-free kitchen decreases eye and lung problems. The toilet connected to the biogas plant also helps achieve better hygienic conditions in the household and surrounding environment. Users' perception indicates the major benefits from smoke-free kitchens are reduced headache, eye infections, coughs and burns. Reduced incidences of illness and health expenses are also anticipated, especially for the women and children, while these improvements in health and sanitation should also raise the social status of the biogas owners.

Studies reveal considerable time saving after installation of biogas, due to less time spent on firewood collection, cooking and washing utensils. Women normally spend two to seven hours each day in collecting fuels for cooking; the median time devoted to collecting wood fuel is approximately six hours per week, resulting in reduced time for agriculture

Biogas system connected to a toilet. Photos by the author

Male member helping with operating the biogas system

and child rearing. The time saved from the use of biogas has also enabled children who were otherwise involved in such household activities to attend school. Mostly the children and women are the main beneficiaries.

It cannot be ignored however that women spend additional time collecting enough water and dung for the digester and fodder for the stall-fed cattle. Despite this, on average three hours' time is saved per household daily, while children have increased educational opportunities. Women have more time to attend to other household chores, care for children and the elderly and do farm work as well as engage in community activities.

Although cooking remains largely the duty of female members of the household, with biogas plant installation this socially-prescribed norm is now seeing changes. There has been an increase in male participation in cooking and sharing the workload of women. The use of biogas has brought significant improvement in the quality of life and reduction in the work load of women. Greater cohesion and cooperation in households were reported as a result of biogas plant installation and the easier cooking arrangements.

Ownership and decision-making

Patriarchal society prevails in Nepal. Men inherit property, so without assets, women are in no position to make decisions including installation of biogas systems on their own. This is further worsened by the inability to take loans due to their incapacity to meet the collateral needs of the financing institutes.

Financial education for the potential owners and sensitisation on economic benefits of biogas has played a key role in the nation-wide proliferation of biogas. But the increase in women's ownership of biogas systems is largely attributed to networking with local financing institutes such as cooperatives which cater to women clients. Annual Reports on biogas reflect a growing ownership by women of nearly 28%. This is also supported by the additional subsidy granted by the government for single women, the poor, Dalits and those in remote settlements.

Normally men are considered as bread winners and decision makers. However, this is slowly changing, influenced by male migration for employment. Women have therefore begun participating more and influencing decision-making at the household as well as community level. According to AEPC, there is an increase in the decision-making role of women where biogas is concerned. A prime factor here is engagement of both the woman and the man of the house in the awareness programs, construction and operations training, a practice mandatory within the biogas program.

Culturally, people do not accept cooking with biogas connected to toilets. It remains a taboo in many households. But upon understanding the larger benefits in terms of quantity and quality of biogas, dignity of women and better waste management around the house, attaching a toilet to biogas plants is now a rising trend. Above all the construction of toilets brought improved health and sanitation for the community. While this decision was tough for family members, especially the elderly, around 80% of households using biogas now have a toilet connection to their biogas plant.

Economic benefits

Studies have indicated that women have greatly benefited from biogas plants in that their overall energy and economic condition has improved. Economic benefits arise from savings on firewood expenditure, women's participation in

Female biogas masons at work

Female quality controllers at work

the paid work and the use of slurry which increases the productivity of farms. Similarly, there are economic benefits from improvement in health and sanitation by using biogas. Biogas has enhanced livelihoods in many ways through the increase in agricultural production.

Women also report on the use of time saved for reading newspapers and education. They also participate in mothers' groups, forest users' groups, cooperatives and other functional groups.
Other economic benefits accrue from the savings on fuel and fertiliser. Considering a household using biogas and the slurry on the farm, a total of 3,460 USD per year is assured to the owner.

Direct economic benefits come from the use of biogas and its slurry, which increase farm production. Biogas also provides employment opportunities. BSPN calculated in 2017 that due to reductions in the use of fuelwood and kerosene, as well as in chemical fertilisers, the annual financial savings are 300,000 NRs, 5,700 NRs and 40,000 NRs, or in total 345,700 NRs per household per year (3,457 USD). In terms of gender benefits, there are six companies now managed by women, employing women as managers, supervisors and masons.

Conclusion

Provision of clean fuel and cook stoves are a first step towards women's economic empowerment. They have played a crucial role in women's welfare and economic empowerment. The biogas programme has made tremendous changes in the lives of rural women, highlighting their role as agents of change rather than just beneficiaries. The biogas program in Nepal demonstrates some important steps for bringing about this transition:

- Need to proactively identify space for women within the biogas systems supply chain
- Provide necessary capacity-building programmes explicitly for women through adoption of enabling environments that comply with the time-availability of women
- Concerted efforts with advocacy, counselling, peer pressure and awareness are necessary
- Coordination and collaboration with local groups such as mothers' groups, forest users' groups and cooperatives provide a more significant impact on women's participation, influence on decision-making and the cooperation of men.

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Fuel Briquettes: An affordable and cleaner cooking and heating fuel

Mary Njenga
Ruth Mendum

The development of innovations that meet people's cooking and heating energy needs and preferences helps to reduce the burden of work for women and girls, while conserving the environment, improving health, and eradicating poverty in sub-Saharan Africa (SSA). Recycling organic waste for fuel briquettes is a promising alternative source of cheaper and cleaner cooking and heating energy while contributing to cleaning urban neighbourhoods, generating income and creating job opportunities, especially for women and youth. This article presents a few examples of fuel briquette production techniques, applied by local community groups in sub-Saharan Africa (SSA), and which can easily be applied in similar situations.

Fuel briquettes in SSA?

Fuel briquettes are a form of energy similar to firewood or charcoal (both referred to as wood-fuel). Fuel briquettes are made by compressing biomass material into a solid unit while using manual or automated presses/machines or other techniques either with or without a binder. Fuel briquettes can be made from non-carbonised (fresh) raw materials such as uncooked food wastes e.g. banana peelings and leaves, maize cobs, rice husks. The biomass materials can also be carbonised (burned under controlled oxygen to remove volatile gases and liquid) before being compacted into briquettes. A binding agent is required while producing briquettes from raw materials that have low agglomerating capacity.

Briquettes are used just like wood-fuel and in similar charcoal and firewood cook stoves, making them a practical alternative or complementary source of energy. Charcoal and firewood are relied on by more than 90% of the population in SSA as a primary source of domestic energy (IEA, 2006). While firewood is mainly used in rural areas, charcoal, on the other hand, is used in urban areas. The demand for charcoal is predicted to increase due to urbanisation and population increase. A 1% increase in population results in a 14% rise in charcoal consumption, despite the fact that there is already a high deficit (World Bank, 2009). Unless the supply of charcoal increases tremendously or the prices fall radically, both unlikely trends, there is need for alternative cheaper sources of biomass cooking and heating energy.

Community-based technologies

One common type of community-based technology is charcoal briquettes. Production of charcoal briquettes is a widespread technique practised by women and youth groups, mainly in urban informal settlements, and involves the recycling of charcoal dust. Charcoal dust comprises small, fine particles and is considered a waste product (heaps of it are visible in charcoal retailing places). About 10-15% of charcoal along the supply chain ends up as charcoal dust (Mugo et al., 2007). Charcoal dust was acquired free till demand for briquettes increased and a customer base was created. The charcoal dust is sieved to get fine particles and remove impurities such as pieces of bone, wood, and stones. The charcoal dust is placed on the ground or in a plastic basin and a binding agent, such as soil, starch or biodegradable paper soaked in water for about 2-3 hours, is added. The amount of binding agent is dependent upon its binding capacity. Some examples of mixing ratios are given below. Water is then added as needed and, using bare hands, the mixture is combined until a homogenous slurry is achieved. Another type of briquette is that made from well-dried raw (non-carbonised) sawdust, which is mixed with gum arabic



(a)Charcoal briquettes moulding in recycled plastic containers and (b) compacted in wooden manual press and (c) sawdust briquettes compacted using metal manual press. All photos by Mary Njenga



(a) Producing charcoal using drum kiln, (b) grinding charcoal and (c) producing briquettes using automated machines by Great Heat in Kampala

resin as a binder. The gum arabic is soaked in water overnight and used the following day. Once the slurry of the raw material and the binder is thoroughly and homogenously mixed it is then compacted using manual metal or wooden presses or moulded using bare hands in the case of charcoal briquettes.

There is a gender issue on choice and preference of compaction technologies, with women preferring simple techniques that require less use of force, such as moulding in recycled containers. Women also prefer presses with handles that allow use of weight as a source of force as opposed to using arms.

Youth are more interested in getting employed in briquette-producing enterprises that use complex machines such as automated grinders, mixers and presses.

There are simple techniques of making charcoal from organic waste. For example, Green Heat, a social enterprise run by youth in Kampala Uganda, works with local communities from whom they buy charcoal produced from banana leaves and peelings using drum kilns. The group use an automated machine to grind the charcoal into a fine dust which is later mixed with molasses as a binder in another automated machine. The mixture is finally transferred to a third automated machine that compacts it into charcoal briquettes.

Utilisation

As a cooking and heating fuel, briquettes are used in similar stoves as firewood and charcoal. There are other uses of briquettes such as keeping chickens warm in chicken hatchery farms and drying tea by small-scale farmers in tea factories.

Benefits

The following benefits can be identified.

- ***Cheaper energy for cooking and heating***. Briquettes are a cheaper form of energy, hence their popularity among low-income populations, particularly in informal urban settlements. For example, cooking a traditional meal of



(a) Drying briquettes on beds in Kampala (b) and on rooftops in Nairobi


(a) Cooking with briquettes, (b) heating space to keep chicks warm. Photos by Trevor Rees



Pots after cooking for 3 hours with (a) briquettes, (b) charcoal and (c) kerosene.

500 grams of green maize mixed with 500 grams of dry beans (enough for a Kenyan standard household of 5 people) costs 3 ksh (US$0.04) when using 850 grams of charcoal-soil briquettes, 26 ksh (US$0.35) using 890 grams of conventional charcoal and 45 ksh (US$0.6) using 0.36 litres of kerosene. Cooking the meal with charcoal briquettes is thus 9 and 15 time cheaper than cooking the meal with charcoal and kerosene respectively.

- ***Income and reduced expenditure on energy for cooking***. Households that produce briquettes for own use and those that purchase them save about 70% and 30% respectively of income spent on cooking energy. Briquette producers generate income, which is hard to do in the informal settlements.
- ***Reduced health risks associated with indoor air pollution.*** Charcoal briquettes made of 80% charcoal dust and 20% soil reduce concentrations of carbon monoxide (CO) and fine particulate matter ($PM_{2.5}$) in the kitchen by 66% and 90% respectively compared to cooking with charcoal. This quality characteristic is influenced by raw material, binder and the production process.
- ***Improved water use and hygiene in the kitchen***. Cooking pots used when cooking with briquettes accumulate no soot and hence require less cleaning, improving hygiene and water use at the household level.
- ***Reduced cost of production***. Using briquettes saves money that would otherwise be spent on electricity bills in order to keep chicks warm or drying tea for example. This increases income of farmers by reducing expenditure.
- ***Resource recovery and reuse.*** The technology is largely based on use of organic by-products in the form of crop or tree residues that otherwise pollute urban areas, especially informal settlements that lack waste management services. Recycling waste reduces expenses incurred by municipalities in transportation and management of landfills.
- ***Environmental management.*** Using briquettes reduces the pressure on trees otherwise cut down for charcoal or firewood. Recycling charcoal dust reduces the global warming potential from the charcoal life-cycle, which includes carbonising trees into charcoal, transportation and cooking.

Recommendations

Despite these benefits, there are a number of challenges that needs to be tackled for community-based briquette production and use. One is lack of land for drying the briquettes, or poor access to water. To solve the water problem, the groups could be trained on simple household wastewater purification for use in briquette production. This is practical as briquette production generally takes place near their homes. Another issue is the access to capital for equipment like high-capacity presses or large drying beds/shelves under shade of translucent roof sheets for enhanced drying. Organised financial support by savings groups or support by local financial institutions is needed. Equal opportunities in accessing land, water and other resources should be given to women and men including the youth, and it is important to respond to specific gendered needs and preferences when improving efficiency in briquette production. For instance, building structures for better drying of briquettes will be more practical than piling up moulded briquettes by hand on the ground. Promotion campaigns such as through television and radio programmes, mobile phones and online edutainment video clips are required to tackle low awareness on the quality and benefits of briquettes in the community and hence low sales. And finally, there is need to integrate briquette making into a proper waste management system aimed at recycling, including development of public and private partnerships in waste collection and use.

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A Commercial Case for the Briquette Business in Ghana

Solomie Gebrezgabher
Sena Amewu

Urban and rural households in low income countries rely on traditional biomass fuels such as charcoal and firewood for cooking and heating purposes, which has an adverse effect on forest resources and on people's health. A major reason for people to continue these as main sources of fuel for cooking is lack of affordable and reliable alternative sources of energy. Briquettes present a great opportunity to replace traditional biomass fuels for domestic and institutional cooking and industrial heating processes. Through designing and implementing a viable briquette business model, we emphasise that there is a commercial case for the briquette business in Ghana.

Non-carbonised briquettes. Photo by Solomie Gebrezgabher

The transformation of organic wastes such as municipal solid waste, market waste and agricultural residues into briquettes, using simple and low-cost technology, has the potential to enhance sustainable development while raising the living standards of the poor in developing countries. Briquettes are an affordable source of energy and can be produced in different forms and shapes for different end uses. The viability and sustainability of the briquette business depends on designing sustainable business models that are cognisant of the existing policy and institutional frameworks, the needs of target end users, acceptance of briquettes by potential users and more importantly the affordability of the briquettes compared to the traditional firewood.

IWMI in partnership with private sector enterprises is designing and implementing a briquette business model in Ghana. To that end IWMI and partners investigated the market environment for the briquette in Ghana with the objective to identify potential market segments. Our study framework is best described as a sequential step-wise approach as shown here:

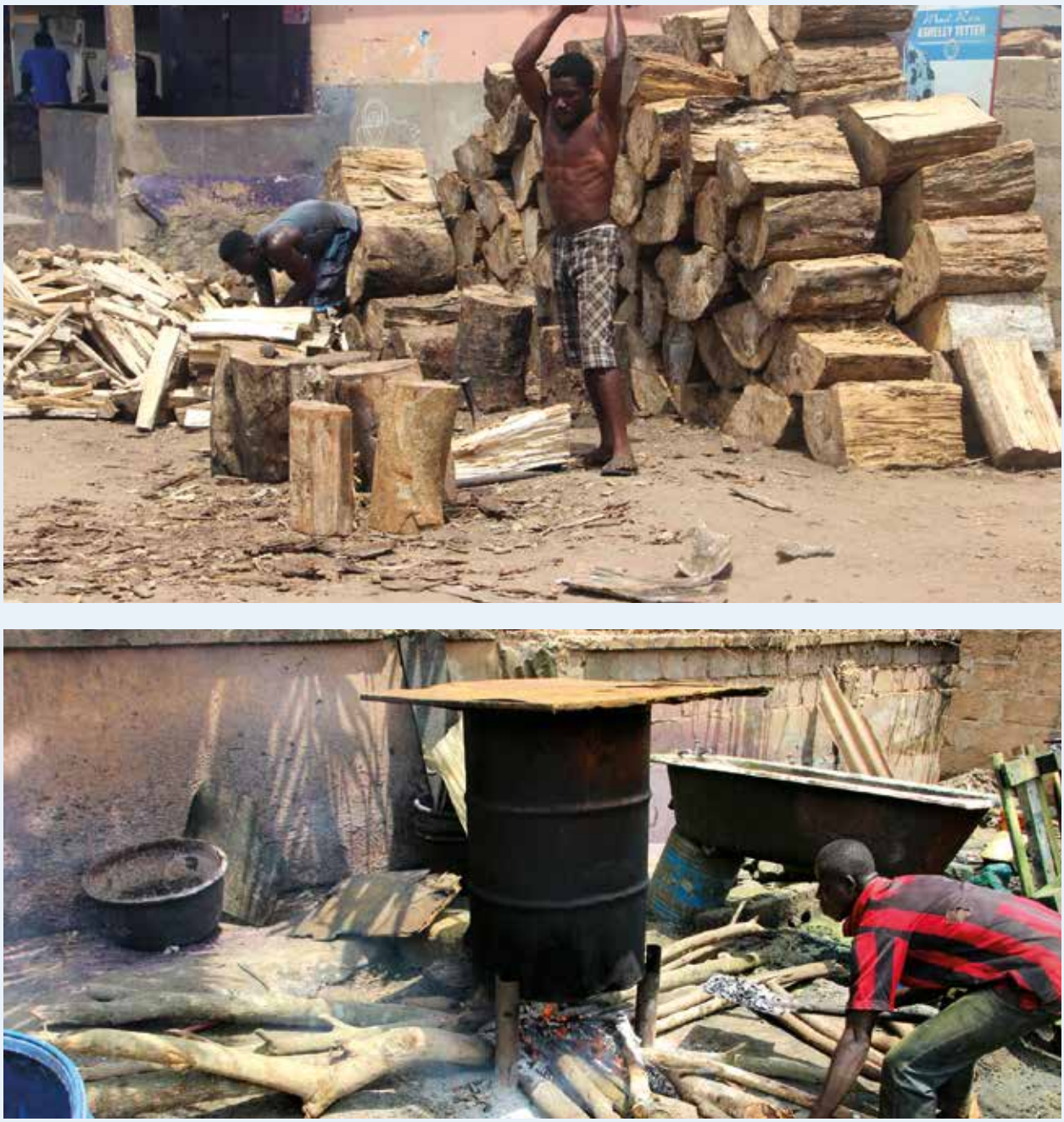
Policy environment in Ghana

Policy support is a key initial driver of the success of any industry and in proposing briquetting of biomass as a sustainable solution to the energy challenges in Ghana, the existence of adequate policy, institutional and legal frameworks is important. Ghana has a number of policies, regulations and institutions in place that support the sustainable use of biomass resources, although biomass briquetting is seldom mentioned. Most of the policies emphasise and encourage the sustainable use of firewood through the introduction of modern technologies that enhance efficiency in the exploitation of biomass resources, introduction of efficient cooking stoves and having a designated area for woodlots, as opposed to promoting biomass briquettes as a replacement for firewood and charcoal.

Briquette enterprises in Ghana - do they exist?

Although several biomass-based energy projects have been undertaken in Ghana with various degrees of success, briquette businesses are not common in Ghana. A few briquette-manufacturing companies, such as Abellon Clean

Steps in designing a sustainable briquette business model



Firewood and traditional stove used for smoking fish. Photo by Sena Amewu

Energy Ltd. and Esereso Carbon Products Ltd., have started operation in recent years with a target to export the product to Europe and India.

Briquette business model – joint venture

The briquette business described in this article is to be implemented as a joint venture between two private sector enterprises, Jekora Ventures Ltd., a waste management organisation servicing the Greater Accra region, and Volta Ghana Investment Ltd., a real estate company operating in Ghana. The key funding principle of the business will be the setting up of a fee-paying waste collection service to communities, and then converting the organic waste into briquettes which are to be sold to different end-users. The value proposition of the business model is that it provides target clients with environment-friendly briquettes that are cheaper than charcoal and firewood. The type of briquette envisaged to be produced by the joint venture is a non-carbonised type, suitable for institutional, commercial and industrial heating processes. Depending on the needs of the different target customer segments, different value propositions using proper channels of reaching each customer segment can be designed.

The briquette business model developed shows key resources, partners and activities required to make the business work. In addition to the resources and activities required for production and selling of briquettes, there is a need for research and development to harness technical and operational competencies and to enable the business to make briquettes that have a standard energy value and consistent properties. Experience from briquette businesses

Women fish smokers

Many engage in smoking fish in the Greater Accra region along the coast. Smoking of fish is carried out using traditionally manufactured stoves and firewood. The kind of stove used by these women may not support the efficient burning of briquettes and this may therefore require the business to supply complimentary briquette-burning stoves. At present firewood is the only fuel source used to smoke fish. It is sourced from surrounding villages and sometimes as far as Kumasi. At Nungua where one can find about 50 fish smokers located in one place, the wood is bought in logs and is then split into smaller pieces, a process that requires a lot of labour.

Batik manufacturers

Batik is a traditional fabric that is manufactured using indigenous technology that involves waxing and dyeing. Large drums of hot water are used in dewaxing the fabric after dying it. All the batik manufacturers visited use firewood in heating huge drums of water using traditional three-stand stoves.

Institutions: senior high schools

Boarding schools that accommodate their students prepare food on large scale. Most of these schools do not depend on a single energy source but on a combination of liquid petroleum gas (LPG) and firewood. Some of the schools source firewood from woodlots on the school's premises at no cost while others buy it. The latter expressed interest in the use of briquettes if it will give them a cheaper and more efficient energy source compared to firewood. There are also schools with biogas installations and these are not considered as potential market segment for briquettes.

in East Africa has shown that these are important factors for the success of a briquette business. Consistent properties of the briquettes with standard energy value can be achieved through research as well as through having the appropriate technical competencies.

Potential market segments for briquettes

Various customer segments were identified as potential target clients for briquettes. These include households, institutions such as high schools and private universities, small and medium scale enterprises, industrial users such as steel product manufacturers, cement factories and breweries. However not all of these segments were found to be suitable for briquettes due to their energy needs, current source of energy and the existing type of stoves used. Customer segments such as fish smokers, senior high schools and Batik manufactures were found to be promising customer segments for briquettes and therefore warrant further studies in order to assess and quantify demand.

Business opportunity

There is a huge untapped market for briquettes in Ghana. Although a systematic approach was used in identifying potential customer segments, the identified segments are not exhaustive and there may exist other viable potential customers for briquettes. These may be either within the cities or even more importantly outside the cities where use of firewood is most dominant. One noticeable fact across most of the potential market segments reached is that most consumers lack awareness and knowledge about the existence of briquettes. Thus, an awareness campaign program needs to be carried out to familiarise target segments on the benefit of using fuel briquettes, including a demonstration of the performance of briquettes in comparison to alternative cooking fuels.

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Fuel Briquettes – Making business sense

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Trading briquettes in Kibera. All photos by IWMI/ICRAF

In memory of Bernice Asamoah

In recent years, interest in fuel briquetting increased because of the opportunity to utilise agricultural residues and the organic fractions of municipal solid waste for energy, with a potential reduction in environmental pollution levels, and where modern heating and cooking fuels for domestic, institutional, commercial and industrial use are not readily available or affordable.

A study was conducted by IWMI and ICRAF (Asamoah et al. 2016.), as part of the project entitled 'Creating and capturing value' (CapVal) funded by the Ghana Wash Window and the CGIAR Research Program on Water, Land and Ecosystems (WLE). The study looked at the entire value chain starting from feedstock to the potential market for briquettes in developing countries. The assessment covered the chemical and physical properties of raw materials suitable for briquette-making, the various production processes, quality and performance characteristics. With the technology now in place, further research looks at market drivers and challenges for briquette businesses, to understand how to build viable briquette enterprises.

Marketing briquettes

Fuel briquettes present multiple potential benefits. Made from renewables, they could (a) be a cheap and sometimes a cleaner source of cooking fuel, (b) generate income through sales, and (c) reduce household expenditure on energy for cooking (see other articles on page 30 and 32). Generating income and lowering household expenditure are critical to achieving poverty reduction. If emissions are reduced, less health problems associated with smoke in the kitchen will appear. Briquettes are more affordable than charcoal, liquid petroleum gas and other cooking fuels, and can thus contribute to food and nutrition security but also support commercial activities, e.g. food processing, poultry farming, brick making, and drying of fish, tea or tobacco. Production of fuel briquettes from municipal solid waste has proven to be successful and the abundance and availability of this waste makes it a suitable, cost-effective and reliable raw material for producing briquettes.

The viability and sustainability of the briquetting business, in addition to suitable technological options, depend on several key factors, including the prices of alternative products such as firewood and charcoal as compared to briquettes, the acceptance of briquettes by potential users, and existing policy and institutional frameworks. Different types of briquettes exist to cater for a variety of applications. In developing countries, the briquette industry is not yet mature, but this is changing in certain regions. Declining wood resources due to overexploitation of forest resources coupled with the consequently rising prices of charcoal and increased urbanisation has resulted in the briquetting business gaining momentum.

The market segments for briquettes can be differentiated into domestic, institutional and industrial use, and for export. The majority of briquette businesses in developing countries supply briquettes to a local or regional market, and only a few briquette businesses are export-oriented. The

most accessible markets for briquettes produced from non-carbonised waste are energy-intensive industries which use firewood for their operations, such as brickmaking, cement factories and other similar industries. Other markets for non-carbonised briquettes are institutional kitchens, such as restaurants, schools and hospitals. Charcoal briquettes are mostly targeted to households and institutional kitchens in rural and urban areas. Globally, there is still low adoption of briquettes in developing countries, which is partly due to lack of awareness, and poor development of the enterprise. For example there is inconsistent supply of quality briquettes on a large-enough scale, whereas firewood is, cheaper and more accessible to many users (for an analysis of Ghana, see article page 32).

Achieving business success

The analysis identified the following drivers for success:

- ***Competition***: Firewood has historically been a cheap and accessible source of fuel for small- and medium-scale industries in many countries. For many years, it has been sourced from forests at no cost or for a very small fee. But this is changing in many countries, creating more room for briquette adoption.
- ***Policy***: Regulations on charcoal have had an influence on increasing the cost of the commodity. Control on cutting down trees and levies on charcoal increase the cost, creating an opportunity for briquettes to compete on a level playing ground. Thus, it is not only regulations directly related to briquettes that can have an impact on the success of briquette businesses, but regulations related to alternative fuel types.
- ***Partnerships***: Strong partnership with key stakeholders such as the municipality, financiers and other actors within the briquette value chain is important for the success of briquette businesses. Lack of access to financial capital is a major bottleneck during start-up and operation of briquette businesses. Partnering with the private sector, for instance, for waste pre-processing and delivery, significantly reduces the cost of production. Similarly, partnering with municipalities or other organisations for resources, such as land, can be important drivers.
- ***Consistency***: Users are sensitive to changes in quality or burning efficiency of their cooking fuel. Thus, it is essential to maintain both quality and consistency of supply. Consistent supply of raw materials with good energy qualities, appropriate technologies, and consistency in the quality and supply of the briquettes are essential.
- ***Marketing***: The quality and characteristics of the final product determine the market value to users. Securing long-term contracts with partners, e.g. with raw material suppliers and bulk buyers of briquettes, can help stabilise the business financially. Off-take agreements with restaurants and institutions, which require large quantities of fuel, are beneficial.

Overcoming business challenges

However, there are challenges and barriers that hinder the advancement of the sector:

- ***Policy***: Regulations that support the production of renewable energy solutions are important in facilitating private and public investment in cleaner cooking fuels. Although many developing countries have renewable energy strategies, briquettes are seldom mentioned in the strategies or policies of these countries and are classified under the broad biomass energy category. Thus, important aspects of the briquettes are not regulated. For instance, policies in solid municipal waste management should enable resource recovery and reuse for briquettes production. Product certification or standardisation of briquettes is missing in many countries, thus resulting in substandard briquettes being produced by many small- and medium-scale businesses. Lack of consistency in quality creates a negative reputation for briquettes, consequently affecting their use. Another challenge related to government regulations is the prevailing poor reinforcement of regulations against the indiscriminate cutting down of trees for firewood. While charcoal production is still unregulated, despite its environmental effects.
- ***Finance***: The investment and operational costs of briquette businesses vary widely depending on scale, technology and types of raw materials used. Access to finance is a major bottleneck for the advancement of the briquette sector and is part of the reason why there are a limited number of briquette businesses operating purely on a commercial basis. Many businesses access finance in the form of grants from local government or international donors, and are faced with difficulties in sustaining themselves after the end of the funding period.
- ***Operations***: Briquettes and/or their benefits are unknown to many biomass fuel users, which makes tapping into the potential market challenging and costly. Without sufficient marketing and distribution strategies, the product is not likely to sell. Further, medium- and large-scale briquette operations face input-related risks which increase the cost of production. For instance, procuring a consistent supply of raw materials in appropriate quantities and desired quality is a bottleneck for briquette businesses. The cost of sourcing raw materials and transportation severely affects the production cost.

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Sunshine for Palestine: Solar energy value chain development in Gaza

Haitham Ghanem
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Photo by René van Veenhuizen

The protracted conflict and the Israeli-imposed blockade have had a devastating effect on Gaza's economy. The movement of people and goods is severely restricted; 90 percent of factories and workshops have had to close; 80 percent of people are in need of aid; and exports recently fell to less than two percent. As part of this, the electricity crisis affects various aspects of the lives of Palestinian citizens.

Realisation of the Gaza Strip's economic potential within this scenario requires various models and interventions. In the case of agricultural development of the Gaza Strip various approaches are under consideration that include urban agriculture, such as re-localisation of food, a reduction of dependency on external inputs and energy, and promoting high-value agricultural products for the local market. The Project 'Facilitating development of Urban and Peri-urban Agriculture for the local market in the Gaza Strip' (UPA GAZA) is funded by the Swiss Development Cooperation (SDC). It is being implemented by Oxfam Italia (Oxfam) and RUAF Foundation (RUAF). The project started in June 2014 and ends in October 2017. Its aim is to increase incomes for women and men engaged in small-scale urban and peri-urban agriculture in the Gaza Strip. The Project supports longer-term systemic market changes and the development of inclusive value chains for small-scale farmers and processors (PU's). It supports intervention strategies in service provision, quality control, and value chain facilitation. It further supports systemic changes in the area of participatory training and extension. This is aimed at enhancing an enabling policy and governance environment.

Energy crisis

The Gaza Strip has been seriously affected by energy shortages since 2006. Private and public buildings, streets and hospitals only have electricity for six to eight hours per day. Services are unreliable, causing dramatic effects on healthcare, schools, and all public facilities. Above all, energy obtained from fossil fuels is unaffordable. Candles used for lighting sometimes cause fires in private housing.

The Current Energy Crisis

Normally, Gaza's power alternates on eight-hour cycles, with generators providing electricity to those who can afford them in the down times. However, since mid-2016, there have been only three to four hours of electricity a day. Gaza gets only 80MW from the ten Israeli feeding lines, while within Gaza itself, the power plant turbines require diesel fuel financed by the Palestinian Authority (PA). The current supply from PA only allows the power plant to provide 20 to 40 MW. Electricity lines provided by Egypt supply an additional 30 MW. The fourth and final source of electricity is individual home solar panels. Though not significant to the total amount of energy, they play an important role for the households of Gaza.

Al Jaleel

There is a good market in Gaza for local dairy products, such as White Cheese and Labna. The project worked with Al Jaleel processing unit, as part of the value chain (in total the project worked with 6 processing units, representing 50% of the total units in Gaza). The project worked on energy, product quality improvement, marketing and in linking to dairy producers. The latter improved the quality of their milk and thus got a better price by working with Al Jaleel as part of the project. Al Jaleel financed 30% of the total investment of the solar panels, batteries and inverters. The 15 KWP hybrid solar system now in use by Al Jaleel reduced the cost by 60%, and had a positive impact on storage capacity and the quantity of milk procured from additional 10 small farmers, as well as quantity and quality of dairy products sold by Al Jaleel. The productivity increased from 1500-2000 liter/day to 3000-3500 liter/day, and Al Jaleeel was able to diversify its cheese products.

Gaza' energy supply comes from three primary sources, namely Israel (160MW), Egypt (37MW) and the Palestine Electric Company (PEC). The amount coming from PEC depends on the amount of fuel available for the production of electricity. On average, the PEC provides around 80 MW (its full capacity is 120 MW), making the total supply of electric power in the Gaza Strip approximately 277 MW. Gaza's electricity needs vary seasonally. During the summer and winter months it requires 440 MW. During the rest of the year it requires 380 MW. So, irrespective of seasonal needs, there is a significant deficit of 100-150 MW through the course of the year. This deficit causes the recurring interruption of electrical supply to homes, economic and service facilities. Solar energy is part of the solution.

Gaza is an energy-intensive growing economy. The shortage of energy affects all activities, including agriculture, along every value chain. Thus, it does not only affect production and cold storage, but also the sale of products as producers and processors are forced to raise prices. Also, retail outlets and consumers along the value chain are equally affected by the energy crisis. They cannot store the fresh products for long. They may also lose trust in the quality of local products in general.

Solar Energy

The biggest advantage of solar energy is its independence from the grid and immediate savings in expenditure on power from other sources, no matter how small the system installed. Solar energy is a modular technology, so one can install as many or as few panels as needed, based on a cost-benefit analysis independent of utility rate changes. There is great potential in Gaza and, since 2014, the solar energy market in Gaza has been booming. According to the Gaza Ministry of National Economy, more than 7MWCheck solar Projects in total have been operational since 2014 up to now. Many international organisations are shifting to solar energy in order to solve the problem of energy shortages in local factories, schools and hospitals. Moreover, many house owners are considering solar energy is the only solution to the energy crises, as long as installation costs are affordable. Establishing new solar energy companies in Gaza is a very profitable business. Back in 2009, only two companies worked in solar energy in Gaza and were lacking in experience. Nowadays, there are almost 10 companies and most of them are well-experienced.

Solar energy for cold storage

Current cold storage facilities in Gaza are insufficient and mainly accessible to larger farmers and traders who can supply bulk volumes of products and pay for the services. As energy supply in Gaza is insufficient, increasingly expensive, and suffers regular breakdowns, solar-powered cold storage facilities offer good opportunities.

The UPA GAZA project focused on the dairy (including fodder production) and palm dates value chains. As part of enhancing service supply to (urban) agriculture, the project supports the development of solar-based cold storage. The aims are increased storage capacity and better quality of fresh products, through staggered or extended time for marketing. Several processing units were considering solar energy, but could not afford the initial high cost of the needed solar systems. Recently, prices have come down, and many funding organisations, for example the Bank of Palestine, have started funding solar energy projects. Other NGOs have joined in stimulating solar energy.

The project adopted co-funding instead of co-investing (and repayment), so as to encourage producers to invest in the development of their businesses. This support is valuated positively by all processing units (Pus) involved. Other producers and processors are also interested in similar agreements. However, further investment is required to improve productivity, to scale up and to improve technical efficiency in the selected value chains, and other value chains.

The project analysed the Gaza solar market and the potential beneficiaries, as to determine interest, willingness and ability to co-finance. This was also done to assess the potential total service supply for solar energy, as part of the value chain and the wider agricultural market. For each beneficiary, responsibilities (including linking to other value chain actors, such as the small-scale dairy farmers or dates farmers and women processors), were agreed in an MoU. In addition, a technical plan and a cost-benefit analysis was done. This covered the investment of the solar installation, as well as the business improvement expected. All solar system components must be ordered from the Israeli market and some from abroad, which made it a lengthy process initially. However, due to the solar energy potential in the Gaza market, many of the solar energy supplying companies began to stock up as much as they could afford of the main

Photo by Haitham Ghanem

solar energy components. They did this in order to be able to compete with other companies when it came to the period of commissioning the project. At the moment of writing, the willingness to invest in solar energy is high. Two of the success stories of shifting to solar energy are Al- Jaleel Dairy processing unit & Al-Ahlia Dates processing unit.

Developing solar energy

Many countries are now exploring ways to stimulate social and economic growth through the development of the renewable energy sector. Investment in renewable energy can generate new sources of growth, increase income, improve trade balances, contribute to industrial development and create jobs. While such socio-economic benefits are increasingly gaining prominence in the global renewable energy debate, specific analytical work and empirical evidence on this important subject in Gaza and Palestine remain relatively limited. Recently, several international and local organisations started to invest in solar energy. For example, the International Finance Cooperation (IFC) and the Coastal Municipalities Water Utility approved a 7MW solar system for the Gaza industrial zone in eastern Gaza, and a 3MW solar system for the Gaza Central Waste Water project.

Al Ahliya

The Al Ahliya Association on Dates works with small- and medium-scale producers and processors. Al Ahliya was involved in the project as a service provider, but also in enhancing women processors' businesses. With Al Ahliya, the project supported the establishment of Balah Palestine, the first women shareholder company for palm date products in Gaza, owned jointly by Al Ahliya, a local enterprise, and by 41 women processors. The project focus was on the improvement of local date processing, cold storage using solar energy (thus extending the season and total production), and in business development. The solar system was installed and operational during the 2016 date season. Balah Palestine managed to store 45 tons of dates, increasing the total amount processed during the extended season by 15 tons, saving 62% on energy costs and assuring quality of processed products, and obtaining an increased income from sold produce, as well as creating an additional income stream from renting out the cold storage room to potato sellers. In this first season, Balah Palestine saw 50,000 NIS (12,500 Euro) in net profit, and created short-term jobs for 75 women and 20 men.

Further use of solar energy in Gaza is being explored currently on:

- Photovoltaic lighting.
- Small-scale cold storage for vegetable farmers and other value chains.
- Domestic hot water
- Solar space heating

Enabling environment support

Sustainable development of renewable energy as an environmentally-friendly option for Gaza during the current crisis is seen as important, as declared by many local and international NGOs. It is necessary to further raise awareness and share information on technologies. Success stories are also needed, and good practices of solar projects implemented by local and international organisations.

The market is developing rapidly, but there are still issues that need attention. Support from the PA is needed to further encourage private sector investments in renewable energy and solar energy specifically. PA also needs to enact renewable resource laws designed to promote private sector development and further enhance cooperation between private sector and government. The PA should also invest in renewable energy projects or adopt tax exemptions, stimulate loans and other financing for private sector and local NGOs or households. Cooperation and coordination with donor organisations and investors is needed to fund renewable energy projects with local NGOs.

Capacity building programs for research centres, universities, colleges and local NGOs on the various applications of renewable energy need to be established. Also, networking between scientific research in academia and the private sector in the field of renewable energy should be enhanced.

Most importantly, the capacity of citizens in the effective utilization of renewable energy needs to be built to further create service provision. For example, local NGOs could assist on techniques and technical specifications of the system to enable local communities to build the system by themselves. Solar power generating systems could also be installed in new buildings, shopping and housing projects. At the least, the facilities needed to be fully ready for future installation of solar energy should be put in place.

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Linking Rural and Urban Areas through Agricultural and Urban Waste Recycling

Francesca Gianfelici, Louison Lançon
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The Linköping Waste-to-Energy (WTE) plant transforms organic waste from agriculture and slaughterhouses around Linköping, Sweden into biogas for fuelling the city's public transport system and to reduce emissions and pollution from the urban transport system. One of the key aims of the Linköping municipality is to develop an integrated system to turn waste into biogas. The waste-to-energy project contributes to coordinating efforts at the city region level in combining waste management activities, sustainable agriculture development, and the decrease of CO_2 emissions. WTE contributes to Sweden's national strategy of overall reduction of food waste.

Linköping is a fast-growing municipality with 153,000 inhabitants located in the heart of southern Sweden. It is the fifth largest municipality in Sweden and capital of Östergötland County (East Sweden Region). The city hosts a university and a number of important industries and is located in the middle of an agricultural district. The farming and forestry sector employs 1.5% of the total labour force.

As part of Sweden's interest in renewable fuels, Linköping identified its public bus system as an opportunity to address rising costs and environmental issues simultaneously. The city decided that the buses should run on locally-produced biogas using locally-collected waste streams, including agricultural and urban waste. Key aims were to develop an integrated system to turn waste into biogas; the system would connect rural and urban areas and improve the environment for Linköping's citizens.

Linkoping Biogas

Linköping Biogas AB was formed in 1995 as a result of co-operation between the City of Linköping, the local abattoir (Swedish Meats AB) and the farmers' association (Lantbrukets Ekonomi AB). Construction work started in March 1996 and the plant began operation in December 1996. Since 2005, the plant has been owned and operated by Svensk Biogas (Swedish Biogas), a subsidiary to the City of Linköping. Over the past few years, the plant has undergone several upgrades to increase its capacity to match the growing demand for biogas.

The Linköping Waste-to-Energy plant uses organic waste from agriculture and slaughterhouses around Linköping. The Linköping plant receives the majority of its waste from three main sources: firstly, different food industries including waste fat, vegetable waste and slaughterhouse waste, secondly, 2,000 tonnes/year of animal manure and thirdly, 36,000 tonnes/year of other waste materials. Together, these total 100,000 tonnes. The waste is mixed with manure at the biogas plant and then pasteurised for 1 hour at 70°C. The material is then fed to the digesters. The digested product is regularly removed from the digester and stored at the plant for a few days before it is transported back to farmers and used as bio-fertiliser.
The plant produces 52,000 tonnes/year of bio-fertiliser for farms in the region. The bio-fertiliser has a dry matter content of 4.5% and a nitrogen content of more than 7 kg/nm^3. It is certified according to the Swedish certification system SPCR120 and thereby approved for recycling to farmland. Since March 2015, all the bio-fertiliser produced in Tekniska Verken's biogas plant is also ecologically certified (KRAV certified).

In 2001, the project was expanded to include waste from school canteens and restaurants, by installing three waste macerators throughout the city. Svensk Biogas currently owns and operates 12 public refuelling stations in Linköping and in the surrounding area. The filling stations are used by private cars as well as by taxis and distribution vehicles from different companies.

Impacts

The Linköping biogas plant has made it possible for the city of Linköping to decrease costs of fuel for their transport system, decrease CO_2 emissions from urban transport, and also to decrease the local emissions of dust, sulphur, and nitrogen oxides. The plant has contributed to farmers' replacing artificial fertiliser, by digesting and providing an environmentally sound process for treatment of the organic waste in the region.

The biogas from the plant replaces about 5.5 million litres of petrol and diesel each year, substantially decreasing the need to import fossil fuels. Biogas production has increased by 334,580 m^3/year, equivalent to 12.65 GWh of renewable vehicle fuel per year. Carbon dioxide emissions have been reduced by about 9000 tonnes each year, while air quality for citizens has also improved. Waste is recycled, decreasing the volume sent to the landfill and, thus, increasing the lifetime of the landfill.

The majority of the produced bio-fertiliser, total 3,422 tonnes/year, is recycled to 17 farms in the surrounding area of Linköping. The bio-fertiliser is managed and resold by Biototal to farmers. Thanks to the production of bio-fertiliser, resource loops are closed and the use of energy-intensive, fossil-fuel-based fertilisers is reduced. The quantity of phosphorus recycled has risen by 689 kg/year and nitrogen by 7,136 kg/year, rather than accumulating in toxic concentrations at landfills.
The project has also contributed positively to the city's economy. Including local farmers in the production of biogas and sale of bio-fertilisers has increased their competitiveness and kept financial flows within the local economy.

Enabling governance structure

Linköping city political and financial support has continued to drive the development of the biogas plant and has supported research. Public funding resources have facilitated the starting phase, and multi-level government intervention guaranteed the upgrading of this plant in the late 1990s as previously described.

Under the heading of 'high-quality urban environments' the Swedish government had set the goal that at least 35% of food wastes from households, restaurants and shops should be recycled through biological treatment by 2010. In 2009, ca. 21% of food waste was treated biologically in various compost and biogas plants. In addition, the deposition of organic waste in landfills was banned in Sweden in 2005. Another target under 'high-quality urban environments' states that, by 2015, at least 60% of the phosphorous in sewage should be recycled for productive purposes, with at least half being returned to arable land. Application of the nutrient-rich residue from the biogas process on agricultural land should help to meet these targets.

Prevention and reduction of food waste is included in the Swedish Waste Prevention Programme, the Swedish environmental policy and the Swedish Waste Management Plan (2012-2017) that introduced national targets for food waste reduction: "by 2018 at least 50% of food waste from households, canteens, shops and restaurants shall be collected separately and treated biologically to secure the recovery of nutrients, of which 40% is treated in a way that energy is recovered also".

Swedish biogas www.swedishbiogas.com/index.php/sv/

Biogas fuelled buses in Linköping municipality

The long-term past history of co-operation among the city, the farmers' association, Linköping University, transportation authorities, and other actors can be identified as the most significant factor contributing to the project's success. Local stakeholders were involved early on and took part in the decision-making process at a very early stage, helping to ensure sustainability and ownership.
Linköping's intervention has already been replicated in other cities, especially in Europe. Today, for example, the entire city fleet of the metropolitan region of Lille (France) is fuelled with biomethane produced from organic waste.

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Biodigestion at the Neighbourhood Level:

From community participation to waste separation

Jolien Hiemstra, Rico Lie and Mark Rietveld

Photo by The Beach Amsterdam

High energy bills and litter on the streets caused a group of residents of the Wildeman neighbourhood in the district of Osdorp in Amsterdam to act. Expecting no solution from the municipality, they decided to take care of it themselves and tackled these two problems with one solution: using the technology of biodigestion to produce energy from municipal food waste - a perfect example of the urban food-waste-energy nexus.

The Wildeman neighbourhood has a relatively low socio-economic profile. Hence, sustainable energy is not on the priority list of most of its residents. Moreover, coordinated waste separation is non-existent in the neighbourhood. An active group of neighbourhood residents, calling themselves 'the Energy Shop' took up these challenges. Supported by "The Lucas Community" and "The Beach", two local social incubators, they decided to bring a biodigester to the Wildeman neighbourhood. In addition to addressing the food-waste-energy nexus, their motivation was to create employment and to improve social cohesion in the neighbourhood. For example, one input for the biodigester is leftover bread, a specific litter problem in some neighbourhoods, as many residents leave this bread for animals as their Muslim belief does not permit them to waste bread.

For the assessment, the Energy Shop contacted Wageningen University and Research (WUR) Science Shop to undertake research. Two MSc students of the research group Knowledge, Technology and Innovation and a WUR student consultancy team (1) took up the challenge, investigating the feasibility of an organic waste separation scheme, the technical requirements for a biodigester at the neighbourhood level, and the overall social conditions and impact of the project.

Community participation in waste separation

The installed biodigester is actually a pilot and is mainly for demonstration purposes. The current pilot is too small to really serve as a viable alternative energy source for the neighbourhood, but the students assessed the technical and social conditions for scaling up the technology to a locally-owned energy production unit. The technical assessment showed that a constant organic waste flow is required and, to make it profitable, the input should at least include all organic waste from the neighbourhood including the bread. To make it work in the absence of municipal collection facilities for organic waste, the collection of organic waste must be organised at the neighbourhood level. The participation of the community in the separation of their organic waste is thus crucial for the project to succeed. One of the observations was that waste collected separately, like glass, paper and textiles, is only reaching a small percentage of its potential capacity. Improving awareness about separate waste collection thus is one of the challenges to be faced.

Convenience

A review of the literature on waste separation behaviour and interviews with residents showed that convenience, knowledge and seeing some kind of benefit from the effort

are the most important factors determining the willingness of the residents to participate in a separation scheme for organic waste. At this stage, we talk about *willingness* to participate, as it is not possible to measure the real participation of the participants since the scheme has not yet been implemented. The results are based on the statements the respondents made in interviews about their actual behaviour as well as their intended behaviour in future, supported by a literature review. Convenience in waste separation seems an obvious factor, but residents stated that current recycling facilities do not respond to this demand; the distance to the facility was too big according to the residents.

Experience in Utrecht: "Bread = Energy" By Jan Deurloo

Care institutions Reinaerde, housing associations Mitros and Portaal collaborated in the autumn of 2014 to tackle the nuisance of leftover bread in Utrecht Zuilen district, sustainably and socially by introducing a bread pick-up and processing service. The municipality of Utrecht is also actively involved as a partner.

Bread = Energy aims for:
- *A clean neighbourhood*
- *An involved neighbourhood*
- *Awareness on food and waste*
- *And energy of own residual waste.*

In Kanaleneiland district the first fermenter is placed in a container in the community garden of Food for Good. The gas will be connected to a stove that can heat the garden house and to a cooking appliance that can be used to prepare garden produce. In Overvecht district an application for an environmental permit is submitted to place a fermenter there. In Zuilen district, they have similar intentions but they have not yet managed to find a suitable place.

They are committed to strengthening social cohesion between vulnerable and non-vulnerable district residents. The bread pick-up service can also be a first step in joining the labour market and closely adheres to the social and sustainable ambitions for the district where the fermenter is located. Participation creates sense and structure in daily life and the low-threshold entry leads to earlier signalling of (increase of) vulnerability and social isolation. With respect for religious and cultural beliefs, they encourage district residents to take the lead: affecting liveability in their own neighbourhood and making energy of collective residual waste.

Photos by Brood = Energie/ Facebook

Knowledge and visibility

The initiator of the project reported that in the beginning he met only disbelief when he tried to explain that energy could be produced from leftover bread. Only after seeing the process of transforming waste into energy were people convinced such a thing is possible. As such, the demonstration biodigester has itself already contributed to increasing awareness in the neighbourhood, confirming the findings of other research that knowledge has a positive effect on recycling intentions (e.g. Ebreo and Vining, 2007). The visibility of a biodigester in the neighbourhood also proved to the residents that their efforts to separate their organic waste does make sense and is important in further support. But when one resident found out about the low energy production of the demonstration biodigester compared to the amount of effort he put in recycling their bread, his optimism about the project dropped. In addition, the research showed that face-to-face promotion was the best way to inform residents about the project. Previous research confirms that awareness of the recycling behaviour of others already triggers people to act similarly (Barr et al., 2003).

Rewarding good behaviour

People want to see the benefit from their behaviour. A reward for good behaviour was therefore also identified as a tool to increase participation. Earlier research showed that low-income groups recycle more when they personally

benefit from it, and this was confirmed by our findings. One respondent mentioned that economic rewards will only work in the short-term. When the consequence of the behaviour is fixed, motivation decreases after a while. Therefore, a feedback mechanism in the incentive system proves to be more successful. Such a feedback loop also stimulates involvement and increases knowledge on one's behaviour, which in turn contributes to participation (Timlett and Williams, 2007).

Social cohesion and social impact

Apart from addressing waste separation and local energy production, the project also has a beneficial social impact. Community participation and collective awareness-raising is in itself considered an important outcome of the intervention. The biodigester demonstration unit only produces gas for a single facility. A small kitchen is used for social cooking activities for residents, closing the circle in bringing people together (see figure). Community bonds are indeed identified as an important factor for future participation in waste separation. Residents liked the idea of producing their own 'Osdorp gas' together with their neighbours. They said that if their neighbours participated, they would do so as well. Social pressure seems to be strong in this neighbourhood.

Benefit of the local

The small-scale character turns out to be an asset in this project. It increases the possibilities for circular solutions because of the short distance between the waste disposal and the user of this waste as a source of energy. In addition, circular initiatives work better on a local level because people can see the process directly in their own environment. This may increase participation rates in waste separation schemes. Moreover, organising things locally creates extra opportunities to connect other community facilities to a project that can contribute to social cohesion in a neighbourhood. Based on the results of the technical feasibility study it is recommended that the energy produced by the biodigester is used for a community facility, for example a restaurant, to follow up on the cooking function of the demonstration unit.

Role of social incubators in the food-waste-nexus

The social incubators played a crucial role in this project. As they are anchored in the community, they receive more trust from its members than public institutions such as the municipality or the waste collection company. This applies to the Wildeman neighbourhood in particular, because trust levels in the government were found to be strikingly low in this area (OIS Amsterdam, 2016). Cooperation with social incubators could therefore be an opportunity for public institutions as it may benefit the acceptance and thus the success of their policies. While intervening in environmental issues such as the food-waste-energy nexus, social incubators intrinsically address community involvement. This case shows that they could serve as a basis for further development of innovations in the food-waste-energy-nexus.

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Notes

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More information:

www.thebeach.nu
www.wur.nl/nl/project/Energieopwekking-uit-brood-en-gftafval-op-buurtniveau-.htm

The Role of the Private Sector in City Region Food systems

Mariëlle Dubbeling

Private sector players are recognised to have the potential to contribute to more sustainable and resilient City Region Food Systems (CRFS). Traditionally, a wide range of private sector organisations have been and are involved in different parts of the food system (from input and service supply to production, processing, retail, catering and consumption). Examples of such private sector players operating in the formal and informal sectors include small, medium and large agricultural farms and production enterprises, food value chain enterprises, individual entrepreneurs, cooperatives, family-run businesses, social enterprises and large corporations.

More recently, players from (urban-based) non-food sectors such as water and energy companies, technological companies, private funds and landowners, social housing corporations and real estate businesses are playing an increasingly important role. Their involvement includes, for example, supporting urban and peri-urban agriculture production, developing short chains and promoting local processing and procurement, developing food hubs in the city region and optimising food waste reduction and re-use. Many of those players are based in and around city regions which are at the centre of supply, markets and consumer demand.

However, information on such private sector roles and initiatives in city region food systems is quite rare. Therefore, RUAF Foundation and the Food & Business Knowledge Platform (F&BKN), with additional support from the CGIAR Water, Land and Ecosystems Research Program (WLE / IWMI) undertook a study in order to better analyse the role of the private sector in building more sustainable and resilient CRFS, to provide suggestions for business and policy support mechanisms and to identify key lessons learned. The study is based on three city region case studies, 19 smaller case studies featuring private sector and government interventions, and a complementary literature and online review. The two overarching questions addressed by this study were:

- How can the private sector help shape more sustainable city region food systems?
- What business and policy environment is needed to better engage the private sector in building sustainable city region food systems?

Examples from three city region case studies

Rotterdam city region food system, The Netherlands

The city region food system of Rotterdam is characterised by a high dependence on national and international trade and a more centralised, consolidated food supply chain with reduced reliance on local production. At the same time, a growing local food movement is developing a number of (smaller) initiatives based on social, environmental and commercial values, including various short supply chains that focus on minimising the distance between producers, retail and consumers in the city region. A specific innovative feature of the Rotterdam CRFS is the role played by a variety of new and non-traditional food players, such as landowners, health organisations, social start-ups and entrepreneurs, energy and water companies, social housing and real estate companies. Social housing and real estate companies, for example, are supporting local (small-scale) urban agriculture production and gardens and facilitating access to land and building stock for other food-related and training activities, such as cooking, They are motivated by social reasons (e.g. Corporate Social Responsibility (CSR)), provision of improved living environments for tenants, and economic reasons (increasing real estate value and reducing the turnover of tenants). The importance of these new players' contribution to more sustainable and resilient food systems is not so much due to the scale of their interventions but to their contribution to creating a supporting environment for food initiatives in the city region. Interventions range from providing access to financial support, land, human resources, knowledge, expertise, networks and peer knowledge to initiating the development and delivery of projects (see also the article on page 48).

Quito city region food system, Ecuador

The city region food system in Quito is characterised by a combination of national and localised food systems. A large number of small and medium-scale producers, local markets and traders still exist alongside a rapidly growing modern and globalised food system which is dominated by a small number of larger processing and retail businesses and greater consumption of processed food. The latter is particularly relevant in the meat, bread and grain-based and dairy sectors where consumer demand is also the highest.

Due to the presence of small-scale producers and intermediaries in the city region and the fact that small and large food processing and retail enterprises are still connected to a local supplier base, there are real opportunities to develop a more sustainable and resilient CRFS in the Quito city region. The Ecuadorian government is very concerned about social inclusion aspects and the government

North Bristol Health Trust catering team with the silver catering mark award. Photo by North Bristol Health Trust

Thursday organic vegetable market. Photo by Veco Andino

stimulates and enforces links to a local supplier base through several support programmes and national legislation. Most striking is a 2014 national policy that stipulates the inclusion of small-scale producers in supermarket distribution channels. A small but growing number of largely high-end consumers are also driving the presence and development of alternative short supply chains, where small-scale producers from the Quito city region directly connect with urban consumer groups.

The potential scale of interventions in, and impact on, a sustainable and resilient CRFS in the Quito city region are quite high considering the (potentially growing) involvement and size of several actors in the food supply chain. There is a large number of small-scale producers, as well as intermediaries and a large processing and retail industry with a dominant market share. Nonetheless, the pressure for the processing and retail companies to be efficient, to offer standardised products and to reduce costs presents challenges and obstacles to small-scale farmers, small enterprises and artisanal entrepreneurs. Those groups particularly struggle with the requirement for regular supply, larger volumes, specific products, hygiene and quality standards, cold storage and transport infrastructure.

Bristol city region food system, United Kingdom

As in Rotterdam, the city region food system in Bristol presents a combination of a globalised and concentrated food system and explicit government and private sector engagement in building a more re-localised food system and a sustainable and resilient CRFS. There is a huge range of food produced and available in the city region but only a small proportion of that is labelled and sold as such to consumers in the city region. Existing networks of community groups, organisations and entrepreneurs, all of whom are interested in good, sustainably-produced food, can be strengthened and form a basis for a more sustainable and resilient CRFS.

In addition, awareness of and demand from institutional buyers, as well as public awareness-raising campaigns, prove to be effective drivers of change towards a more sustainable and resilient CRFS in Bristol. In Bristol, (and in the UK generally, a novel catering mark scheme is used by a significant number of public sector buyers such as hospitals, schools and universities. The Food for Life Catering Mark is a voluntary accreditation scheme with a focus on provenance and traceability. North Bristol NHS, for example, prepares 3000 meals a day for Southmead Hospital in Bristol under this scheme. Eden Food Services, a national catering company that also adheres to the catering mark, holds Bristol City Council's contract to provide school meals in 126 schools in the Bristol city region. Driven by strong public pressure for improvements to school and hospital meals, the catering mark proves to be an effective tool for driving qualitative change in public sector catering while providing unique opportunities for city region producers, processors and other suppliers.

Other private sector players and innovations

Additional private sector cases showcase how mainstream business models can include innovative and more sustainable food system strategies that make a difference at a city region scale. These include examples of large-scale retail and catering enterprises involved in food waste reduction, local or regional sourcing and on-site food production, for reasons of social and environmental responsibility and marketing and in response to consumer demand. Among these are airport food shops run by Autogrill and HMSHost, international hotel chains such as Accor hotels, which include Pullman, Sofitel, Novotel, Mercure and the Ibis chains, local hotels in Rosario, Argentina and some supermarket chains in Brazil, Ecuador and the Netherlands.

A growing role is also played by technology companies (including companies like Philips, Sharp and Panasonic) engaged in urban food growing for urban markets (such as vertical farming, rooftop or indoor greenhouses) or in supplying technologies to urban food production companies. They do so to increase asset value (for example of unused production facilities), to benefit from incentives offered through building certification schemes and to create new revenues (for example LED light or hydroponic plant growing systems).

The development of more sustainable and resilient CRFS also offer opportunities for waste and electricity companies (including documented examples from Brazilian, French,

Local food promotion and trade in Ontario. Photo by Henk Renting

Ghanaian and Swedish enterprises), as large volumes of food and organic waste are generated in the city region food supply chain. Their engagement is driven by environmental and economic values (recycled waste products like compost or fertiliser briquettes and new energy products like biogas may have a market value and job creation potential). New financing models such as carbon credits (as applied in Brazil and Quito) may be used to recover investments.

Promising examples of policy support mechanisms

Whether at local, regional or national levels, public policy support to private sector engagement and behaviour in building more sustainable and resilient CRFS is driven by interest to mobilise private sector investment and resources, as well as to enhance environmental, social and economic development objectives and to advance innovations.

Support mechanisms include legal and regulatory instruments, such as setting of procurement standards and targets (as done in Rome, Malmö and Ecuador), and 'green' building regulations, zoning and agricultural land protection (as done in Toronto, Rosario and Belo Horizonte). They also include financial instruments (like public or public-private investment funds as developed in Quito, Linköping and Ontario, as well as taxes and subsidies). Many of these governments also deliver complementary strategies including communication and education, direct implementation or support to CRFS projects such as urban farmer markets or urban agriculture projects and provision of business support services including granting access to land, markets, infrastructure and resources, but also encompassing training and advice.

Governments and public institutions can also generate large buyer demand for city region products through their own public procurement, for example in offices, schools, hospitals and prisons). In order to enhance impact in various domains, it is important that, apart from provenance criteria, emphasis is given to aspects of health, social justice and inclusion, regional employment and environmental sustainability.

Business characteristics supporting city region food system engagement

The cases shed more light on the specific characteristics of food businesses located in the city region that seem to have the highest potential to supply city region markets and provide or source city region products. A set of business characteristics that are common to many of these private sector players emerges:

- City region markets make best economic sense for small to medium-size enterprises (SMEs) that have relatively low levels of overhead and low levels of profit extraction. These also offer flexibility and a wide range of skills enabling engagement in different production, processing, marketing and other services.
- Regarding ownership and behaviour, businesses that are family run, run by a small partnership or have sole owners that keep labour costs low (family labour) appear to drive human-scale operation and affinity with the region and take pride and passion in connecting to local suppliers. Such businesses are often based on long-term relations that motivate them to offer good quality food to their consumers with whom they also may have more personalised relations.
- They make efficient use of capital inputs such as by sharing infrastructure and accessing suitable processing and distribution facilities (i.e. in terms of distance, volumes, quality, equipment, skills, and specialisations). Businesses do this either individually or through collective ownership, or where they are offered by other private sector partners or the government
- They access both local and mainstream markets, which requires amongst others the ability to supply sufficient volume and offer proof of traceability
- They have retail control of their own markets, for example through short supply chains, internet platforms, or by offering both production and catering services at the same location
- They can innovate and respond to quickly-changing consumer demands and needs.

These observations do not deny the potential of large scale processing, retail and catering businesses such as supermarkets, hotel and restaurant chains to drive important change due to their scale of operation and financial resources, as earlier examples have demonstrated. However, the observations seem to show that their impacts on other sustainability and resilience areas, such as local job creation and social inclusion, are more limited. Although such larger enterprises could generate impact by offering supply and job opportunities to local farmers and SMEs, this often requires government regulation or incentives, as well as consumer demand and business awareness.

Advocating a cooperative and food supply chain approach

Challenges for smaller and medium-scale private enterprises generally lie in volume (bulk) requirements and price settings, product quality and standards. Economies of scale can be created by consumer cooperatives or other pooling of consumer groups as done by some community supported agriculture (CSAs) or internet buyer groups. Product aggregation can also operate through producer cooperatives or other intermediaries, while collaboration among SME and mainstream private sector players is another strategy documented in some of the case studies. Examples include

Toronto Food Share mobile retail outlet. Photo by Lauren Baker

alternative, value-driven local food players integrating their products into mainstream distribution (like supermarkets) or mainstream companies (such as Catering Mark award-holding caterers or national and international chains such as Santa Maria supermarkets in Ecuador, Autogrill airport caterers and Accor Hotels). This increases their procurement of locally-sourced products.

Product and market innovation can be a solution to address affordability by both addressing (higher-end) niche markets as well as lowering production costs. Examples for reducing costs include changes in packaging material, creating specific input supply channels for SMEs as done in Brazil or sharing infrastructure and resources as done in Rotterdam.

Direct producer-consumer relations based on trust, local guarantee schemes and accreditation (see Quito and Rosario examples) and catering mark schemes (e.g. Bristol) are strategies to deal with required product provenance, traceability and quality guarantees.

The impact of private sector contributions to sustainable and resilient CRFS seem to be highest if a food supply chain approach is advocated, where support is not provided to individual businesses but to the entire network of city region producers, wholesalers, processors, caterers and shopkeepers.

Further business support would need to evolve around the setting up and improving of (shared) processing, storage centres or food hubs, ICT services, commercial and logistics training. Up-to-date information on the food system (food supply sources, retail market and consumption trends) is required. Businesses also need to better understand the options available around contract specification and contract management, the availability of products, and the other businesses that can help them with sourcing and supporting the case for doing it. Consumer awareness and education on the benefits of city region food supply are also needed. Catering certification schemes are proven mechanisms to drive systemic change.

Business behaviour

Private sector players themselves can also take various steps to increase their engagement in sustainable and resilient CRFS. These include:

- Applying local or regional procurement and sourcing criteria (retail and catering businesses)
- Targeting city region markets: establishing direct relationships with retail buyers and consumers in the city region, providing new product concepts and innovations and specific urban services
- Aligning CSR strategies and resources with a sustainable and resilient CRFS vision by promoting or directly engaging in local sourcing, own production, food waste reduction and management, links with small-scale producers, SMEs and social enterprises
- Pooling production, sharing infrastructure or resources and grouping consumer demand
- Pioneering innovations that include social inclusion criteria
- Innovating financing: for example use of carbon credits (see Quito experience) or public-private partnerships
- Developing business relationships and networks with both mainstream and other CRFS business partners, customers and public sector stakeholders.

City regions offer some unique opportunities to traditional and new private sector players given the presence of large consumer markets, opportunities for more direct consumer relations and close collaboration between different players in the food supply chain. The increased recognition of the role that food plays in responding to various urban sustainability concerns also offers new market and engagement opportunities.

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The full study report and three city region reports can be accessed here: www.ruaf.org/projects/role-private-sector-city-region-food-systems

Harvesting the Non-Food Benefits of Urban Agriculture: Finding and engaging unexpected partners?

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Paul de Graaf

Photo by Hotspot Hutspot

The city of Rotterdam is characterised by the paradox of being an international port - a gateway to Europe, particularly for fruit and feed ingredients - while at the same time having a small but prolific regional food movement. This movement consists of citizens and entrepreneurs with strong local connections who are motivated by environmental and social aims. A wide range of private sector actors and departments within the municipality are pursuing aspects of a more regionally-oriented food system.

Food is not the only driver

What, at least in theory, connects the diversity of actors in this mix of local and global orientation is the idea that Rotterdam should strive to become a more enjoyable and more sustainable place to live and work. An integrated city region food system could be part of this ambition, but many actors involved in food are not primarily interested in the food system itself, but rather focus on other benefits that it offers the city. These benefits include environmental services, improvement of public health and social justice, education, employment and reintegration. Other benefits that a more integrated city region food system can deliver include reduction of energy use or energy production and better ways of handling and reuse of waste.

Non-traditional food actors

In Rotterdam, we see an increasing participation of actors who are traditionally not considered part of the food sector such as public health organisations, schools, social housing companies, commercial real estate, innovative start-ups, proactive NGOs and social entrepreneurs.
They are primarily driven by a wide range of urban motives. These range from improving social cohesion, improving public health and building a sustainable future to securing real estate value by providing a beautiful and appealing living environment. The actors' involvement ranges from providing access to financial support, land and project development to providing access to human resources, expertise, networks and peer knowledge. For example, private funds from the Rotterdam region that support social, cultural and/or environmental goals have facilitated city food region initiatives through grant support. Typically they support events, and invest in materials and consumables such as plants, containers or kitchens. The Dutch Rabobank (originally a cooperative with a focus on agriculture) offers regional funds, to support food initiatives by local citizens and entrepreneurs as part of their Banking4Food strategy.

Food and real estate

It is striking that *social housing corporations* (SHCs) such as Havensteder, Vestia and Woonstad Rotterdam, as well as commercial real estate developers, have played an important role in facilitating urban agriculture and food-related initiatives by providing access to land and financial support. They own vacant land and office space that was not immediately being developed due to the economic crisis. For urban food-related initiatives, access to space both for production and retail activities is essential, and access to temporarily unused land or vacant office space is one way to avoid the competition for scarce and valuable space in the city. Vacant land is turned into a collective "edible" green space. Vacant office space is turned into a neighbourhood restaurant that teaches children to cook. SHCs appreciate the benefits of such initiatives as they have the potential to

Table 1: Overview of non-food private players, the nature of their involvement and their motives

Private sector type	Nature of involvement	Private sector actors in Rotterdam	Motive
Private funds	Financial	Volkskracht	Social cohesion, empowerment
		Verre Bergen	Education, empowerment
		Fonds Schiedam-Vlaardingen	Public space improvement
		iFund	Impact investment
Social housing corporations	Financial; access to land; initiating	Havensteder	Neighbourhood improvement
		Vestia	Neighbourhood improvement
		Woonstad	Public space improvement
Real estate developers	Financial; access to land	Dura Vermeer	Corporate Social Responsibility
		AM	Placemaking
		Provast(Markthal)	Real estate development
		CODUM/ZUS (Schieblock)	Urban regeneration
Land owners	Access to land	Natuurmonumenten	Multifunctional green space
		Trompenburg	Attract new visitors
Providers of essential flows	Access to resources / financial	Evides	Providing water
		ENECO	"Green for red" compensation for development infrastructure
Engineers, consultants architects& planners	Access to (technical) knowledge, expertise expertise	Priva	Innovation; learning; development new business opportunities
		BAM	
		Tauw	
		ARCADIS	
		Rotterdam Metabolists	
Care & reintegration organisations	Access to human resources; coaching; initiating; access to land	De Stromen Opmaat Groep (Aafje)	Corporate Social Responsibility
		WMO Radar	Reintegration, social work
		Pniel	Social cohesion, empowerment
		Magis010	Reintegration
NGOs	Providing a network; access to peer knowledge	Slow Food / YFM	Knowledge exchange
		VELT	Connecting, representation
		Eetbaar Rotterdam	Shared interests, food literacy
Social Entrepreneurs	Initiating, development and execution; entrepreneurship	Vakmanstad	Education, empowerment; food literacy; health
		Rotterdamse Munt	Empowerment; food literacy
		Voedseltuin	Empowerment; food literacy
		Proefhof (Kook/Oogst met mij mee)	Education, empowerment, food literacy
		Buurtlab	Education, food literacy
		Rotterdams Forest Garden Netwerk	Education, empowerment; food literacy; eco literacy
		Moestuinman	Education, empowerment; food literacy; eco-literacy
		Caroline Zeevat	Food literacy, social inclusion
		Bob Richters, Mireille v.d. Berg	Education, empowerment, food literacy, social design
		Ester van de Wiel	Social design
		Rotterzwam	Sustainability, blue economy
		Uit Je Eigen Stad	Innovation; sustainable food system; food literacy

Photo by Hotspot Hutspot

increase social cohesion and the quality of shared and public spaces and to improve a perceived 'sense of place'. Commercial real estate developers now also consider an urban farm as a facility for residential urban development, or even as a central force for area development.

The same mechanism can be observed in the way food distribution and retail are used as drivers for urban development. As high streets are under increasing pressure from web shops, retail property developers are looking to develop different shopping experiences. As demonstrated by the privately-developed food halls Markthal and Fenix Food Factory, food offers plenty of opportunities for an enjoyable shopping experience through smelling, tasting, touching and eating, all things that cannot be done through the internet. It is assumed that this will reflect on real estate value, i.e. increasing or at least maintaining value. Such initiatives also have the potential to extend the average time of residency for inhabitants in the neighbourhood. This can translate into savings and profits from a real estate point of view.

Four examples of food system support by SHCs or real estate developers can be given. At *Uit Je Eigen Stad*, an urban farm on a derelict site in the Rotterdam area, the SHC or private developer roles are site design and building services, with the pre-investment to be recovered through rent. At *Hotspot Hutspot*, a pop-up restaurant that teaches children how to cook from scratch, the SHC role is to provide financial support as well as access to land and building space. *Stadslandbouw Schiebroek* is a network of urban gardens for residents in a social housing neighbourhood where the SHC role is providing access to land and water as well as hiring of a coordinator or coach).The already-mentioned *Markthal* is a retail real estate project with a focus on food where the owner of the Markthal rents out space. Their motives vary and include corporate social responsibility, asset value addition and place-making. SHCs may have a longer term relation with urban food initiatives than real estate agencies do. Most food-related projects, such as Hotspot Hutspot and Stadslandbouw Schiebroek that are supported by SHCs, directly benefit their main target group: the tenants of social housing. A longer-term commitment, and one that combines different support strategies, seems to be the most successful.

There are also various private land owners who make some of their land available to food production or related activities. Inside the city for example, Trompenburg Gardens and Arboretum are planning to turn 1.2 hectares of its 8 hectares public gardens into a food forest in collaboration with, and initiated by, a group of social entrepreneurs.

Social entrepreneurship

Social entrepreneurs form an important part of the urban landscape, not just in the area of food production but also in terms of social cohesion, social care and job coaching (Bakker, 2016). Projects often attract volunteers who are able and willing to support the social entrepreneur in engaging the usually-disadvantaged target group. This is the participative society at its very best. These projects supplement urban social welfare in the conventional sense. They are more flexible but also often less) professionally-recognised than more traditional public or private services that are financed by local government or private foundations and whose management has professional stamps of approval. A lot of projects that SHCs support are initiated by such social entrepreneurs.

Yet social food entrepreneurs in Rotterdam are under constant pressure to get absorbed into the formal social welfare system. They are pressured to apply for municipal and philanthropic funding, to engage in social media contests to win extra resources or to cut back on their own standards of living to navigate periods of lack of funding. For example, most social entrepreneurs are not properly insured and do not save for a pension. It should also be noted that the more dependent an urban food initiative becomes on income from sales, the more restricted they become in terms of people who can participate. Further, social entrepreneurs are 'competing' over easy-to-engage target groups and they may also 'compete' for volunteers who are able and willing to work in this increasingly challenging environment.

Engagement of other non-traditional food actors

Social care and rehabilitation organisations are involved in food-related activities as part of their work to help people heal or enable them to get back to work. Traditional utility companies such as those supplying energy and water have

had only very limited engagement in developing specific solutions to support short food supply chains. But some innovative projects have emerged. Between 2006 and 2009 the energy company E.ON was a partner in a project that used waste heat from its plant in the Rotterdam port area to grow tropical shrimps (Happy Shrimp). Other initiatives have developed around the safe re-use of food waste for human consumption. This is done by the Food Bank and also by pop-up restaurants such as Hotspot Hutspot. These initiatives target people with low income and are therefore socially inclusive by design. Another initiative is the start-up Kromkommer that turns discarded (odd-shaped and surplus) vegetables into products such as soups and now also supplies supermarkets. This wide range of food system innovations also attracts engineers and consultants, such as suppliers of technological solutions as well as engineering firms.

Encouraging non-traditional players in the food system

These examples show how the value of agriculture or food production is no longer measured only in the food produced but in a range of services to the city. The involvement of new private sector players in building city region food systems can be explained by a growing awareness of these benefits, and of practical ways to valorise them. This is also a key to encouraging further engagement. Social entrepreneurs are very engaged but their contribution could be bigger if there was a more clear and consistent policy from the municipality. Financial support should develop from *ad hoc* grants to more systematic support, rewarding the environmental and social services that these initiatives provide to the city. It is interesting to consider that the notion of a CRFS connects a lot of different parties for whom food is not a first priority. Food is a powerful way to connect these diverse parties, but it cannot be expected that these parties will produce an overarching strategy that stretches beyond their own interests. The same can be said of most of the (inter)nationally oriented food sector actors that are based in Rotterdam. In their case, they are less committed to the city region scale because they can move their operation elsewhere if necessary. Companies with a place-based background however, particularly family businesses that have a history in the area, are more likely to innovate at the city region scale. To be sure, these companies operate within international market circumstances, but their commitment is not just to profit. Inspired by local initiatives, they have the ability to scale up innovations from a micro-(neighbourhood) level to a regional scale.

A common narrative

It is important to engage the private sector actors on their own terms. To them, the non-food benefits are the most valuable. They can help capitalise these benefits in a way that can support the development of a more integrated city region food system. However this implies the need for a policy environment that enables this by connecting the different motives of the private partners. To have a diversity of private parties be part of an integrated city region food system demands a common narrative that gives each part its place. This narrative does not have to be a shared vision, but should give room to the constituent parts to pursue their own priorities in mutually supportive way. Their activities and the beneficial side-effects, such as a diversity of ecosystem and social services, are independent but constituent parts that support the development of the city and its food system. A policy environment that acknowledges the broader impact of food-related activities and stimulates private parties to actively engage in these activities and benefit from their services could offer such a narrative meeting ground.

Recommendations for a supportive policy environment

Lessons from studying the Rotterdam context can possibly be of value elsewhere. We identified the following list of recommendations:

At municipal level:

- help to reinforce and quantify the multiple benefits of urban and peri-urban agriculture for city region food systems, and support efforts to explicate, accredit and reward best practices
- support social entrepreneurship more consistently and strategically
- connect short & long food supply chains and investigate their possibilities for synergy, such as shared logistics or shared labour market
- support an open climate of innovation that is market-driven rather than technology-dominated and reinforce the social values around food
- address potential conflicts (for example over space, access to funding or markets) and make priorities explicit
- engage more actively with iconic food-projects such as the Markthal and Fenix Food Factory
- engage more actively with planning rural land uses around the city and stimulate managing this as multifunctional agricultural parks where food production, recreation and biodiversity go together more harmoniously
- coordinate municipal activities, funding and the exchange of knowledge and experience with private actors that have similar goals, e.g. in the case of sustainable renovation of the housing stock SHCs and property developers should be invited to work together with the relevant municipal departments
- record and update municipal intentions in a food strategy which states concrete actions and goals.

At the regional and national level:

- incorporate non-food benefits in agriculture policy
- link rural development with city regions economically, socially and spatially
- match regional, national and EU agriculture funds with urban food policy ambitions and aspirations
- appreciate the flexibility of private sector players, who will carve out their own role in the continuously-evolving food policy narrative.

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Upcoming issues of the Urban Agriculture Magazine

Urban Gardens "Tre Fontane" in Rome. Photo by Maria Caterina Feole

November 2017

This issue of Urban Agriculture Magazine is a joint effort of RUAF and the Centre for Agroecology Water and Resilience at Coventry University. It contains:

- Contributions that explore ways of conceptualising urban agroecology.
- Articles that focus on exploring practices and city initiatives related to urban agroecology.
- Articles that focus on the role of urban policies in supporting agroecology.

The Magazine will be launched at the 8th AESOP conference on Sustainable Food Planning, titled "Re-imagining sustainable food planning, building resourcefulness: food movements, insurgent planning and heterodox economics" in Coventry, November 2017.

Other upcoming Urban Agriculture Magazines

- Urban Agriculture and Youth Employment: June 2018. Please send us your ideas or articles before March, 1 2018.
- Urban Agriculture Technologies, November 2018

Look for our call for contributions that will be published on the RUAF website but you can share articles or proposals already with f.hoekstra@ruaf.org.

Articles for upcoming Magazines

Articles should be a maximum of 2000 words (three pages), 1300 words (two pages), or 600 words (one page), preferably accompanied by an abstract, a maximum of 5 references, figures and digital images or photographs of good quality (more than 1 MB). The articles should be written in a manner that is readily understood by a wide variety of stakeholders all over the world.

Please clarify in your article the concepts used. Also, present where these experiences were gained, and the main actors, impacts, related costs, problems/challenges encountered and solutions found, the major lessons learned, and recommendations for both practitioners and planners or policy makers.

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UA Magazine facilitates the sharing of information on the impacts of urban agriculture, promotes analysis and debate on critical issues for development of the sector, and publishes "good practices" in urban agriculture.

UA Magazine welcomes contributions on new initiatives at individual, neighbourhood, city and national levels. Attention is given to technical, socioeconomic, institutional and policy aspects of sustainable urban food production, marketing, processing and distribution systems. Although articles on any related issue are welcome and considered for publication, each UA Magazine focuses on a selected theme (for previous issues, visit: www.ruaf.org).

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