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Sustainable Agriculture and Off-Grid Renewable Energy

Small integrated farms with off-grid renewable energy may be the perfect solution to the food and financial crisis while mitigating and adapting to climate change Dr. Mae-Wan Ho

ISIS contribution to UNCTAD Trade and Environment Review 2011, ASSURING FOOD SECURITY IN DEVELOPING COUNTRIES UNDER THE CHALLENGES OF CLIMATE CHANGE: CONTINUING WITH BUSINESS AS USUAL APPROACHES IS NOT AN OPTION

In a Nutshell

An emerging scientific consensus that a shift to small scale sustainable agriculture and localized food systems will address most, if not all the underlying causes of deteriorating agricultural productivity as well as the conservation of natural soil and water resources while saving the climate

To substantially improve living standards, access to modern energy is also crucial. Small agro-ecological farms are known to be highly productive, and are ideally served by new renewable energies that can be generated and used on site, and in off-grid situations most often encountered in developing countries

A model that explicitly integrates sustainable farming and renewable energies in a circular economy patterned after nature could compensate, in the best case scenario, for the carbon emissions and energy consumption of the entire nation while revitalising and stimulating local economies and employment opportunities

Food crisis, global economic instability, and political unrest

Soaring food prices were a major trigger for the riots that destabilized North Africa and the Middle East, and have since spread to many other African countries [1, 2]. The UN Food Price Index hit its all-time high in February 2011, and the May 2011 average was 37 percent above a year ago [3]. This is happening as the global economy is still staggering from the 2008 financial (and food) crisis, with public debt expanding and unemployment sky high [4].

Lester Brown, venerated veteran world-watcher, says food has quickly become the hidden driver of world politics [5], and food crises are going to become increasingly common. “Scarcity is the new norm.” The world is facing increasing demand for food as population increases while food crops and land are being diverted to produce biofuels; in 2010, the United States alone turned 126 million tons of its 400 million tons corn harvest into ethanol. At the same time, the world’s ability to produce food is diminishing. Aquifers are running dry in the major food producing countries where half of the world population live. There is widespread soil erosion and desertification; and global warming temperatures and weather extremes are already reducing crop yields [6-9], hitting the most vulnerable people in sub-Saharan Africa and south Asia the hardest.

"We are now so close to the edge that a breakdown in the food system could come at any time." Brown warns [5]. "At issue now is whether the world can go beyond focusing on the symptoms of the deteriorating food situation and instead attack the underlying causes. If we cannot produce higher crop yields with less water and conserve fertile soils, many agricultural areas will cease to be viable…..If we cannot move at wartime speed to stabilize the climate, we may not be able to avoid runaway food prices….The time to act is now -- before the food crisis of 2011 becomes the new normal."

The importance of small family farms

There is an emerging scientific consensus that a shift to small scale sustainable agriculture and localized food systems will address most, if not all the underlying causes of deteriorating agricultural productivity as well as the conservation of natural soil and water resources while saving the climate [10-13].

Small, family farming is the dominant form of agriculture in the world, especially in the developing world of Africa and Asia. Approximately 3 billion people live in rural areas in developing countries, which also include 80 percent of the poor in the developing world. Around 2.5 billion are involved in agriculture as farmers or workers, and at least 75 percent of farms in the majority of Asian and African countries are 2 ha or less [14]. As Ulrich Hoffmann points out [12], MDG (Millennium Development Goal) 1 aims at eradicating extreme hunger and poverty; and one of the most effective ways of halving both the number of hungry and poor by 2015 is to make the transition towards more sustainable forms of agriculture "that nourish the land and people and provide an opportunity for decent, financially rewarding and gender equal jobs." It would at the same time meet health targets from MDG 3 and 6 in providing a more diverse, safe, nutritious and affordable diet (see also [10]).

Notably, small farms generally produce more per hectare than large farm; so much so that economists have long observed and debated this apparently paradoxical inverse relationship between farm size and productivity [14]. Small farms are 2 to 10 times as productive and much more profitable; and not just in the developing world [15]. A US Agricultural Census in 1992 found a sharp decline of net income from $1 400/acre to $12/acre as farm size increased from 4 to 6709 acres [16].

Small farms are associated with [14] "intensive use of household and community labour, high levels of motivation and much lower supervision and transaction costs", which may well account for the economic advantages, but not the actual productivity. Small farms are highly productive because they are typically biodiverse systems integrating multiple crops and livestock that enable them to maximise synergetic relationships while minimizing wastes; turning wastes such as farmyard manure into fertilizer resources. In effect, they embody the circular economy of nature [10] where energy and nutrients are recycled within the ecosystem for maximum productivity and carbon sequestration both above and below ground. This 'thermodynamics of organisms and sustainable systems' is derived and explained in detail elsewhere [17].

The importance of renewable energy

To substantially improve living standards, sustainable farming is not enough, access to modern energy is also crucial. Lack of access to modern energy is generally recognized as the biggest obstacle to sustainable development. The International Energy Agency 2010 report on energy poverty stated [18]: "Lack of access to modern energy services is a serious hindrance to economic and social development and must be overcome if the UN Millennium Development goals (MDGs) are to be achieved." This view is echoed in the report of the 6th Annual Meeting of the African Science Academy Development Initiative (ASADI) [19]: "Access to modern energy services, defined as electricity and clean cooking fuels, is central to a country's development."

Worldwide, 1.4 billion people lack access to electricity, 85 percent in rural areas, and 2.7 billion still rely on traditional biomass fuels for cooking and heating [18]. The greatest challenge is sub-Saharan Africa, where only 31 percent of the population has access to electricity, the lowest level in the world. If South Africa is excluded, the share declines to 28 percent.

There is close correlation between income levels and access to modern energy. Countries with a large proportion of the population living on an income of less than $2 per day tend to have low electrification rates and a high proportion of the population relying on traditional biomass.

The World Health Organization estimates that 1.45 million people die prematurely each year from household air pollution due to inefficient biomass combustion; a significant proportion young children. This is greater than premature deaths from malaria or tuberculosis.

Small agro-ecological farms are ideally served by new renewable energies that can be generated and used on site, and in off-grid situations most often encountered in developing countries [20, 21]. The renewable energies generated can also serve local businesses, stimulate local economies and create plenty of employment opportunities.

Off-grid renewable power systems entering mainstream worldwide

Within the past few years, off-grid power systems have entered the mainstream, driven by the ready availability of renewable energy options that can cost *less* than grid connections.

A UK company advertises on its website [22]: "Homes across the UK and Europe are looking at the potential benefits of supplying some, if not all their domestic power requirement from off-grid sources" for a variety of reasons: connection to the grid is too expensive, reducing energy bills, protect from power cuts and reduce greenhouse gas emissions. Solar panels, wind turbines, and small generators are suitable for most homes, and a system with a battery connected to a battery charger/inverter is the most convenient.

The UK government Office of Fair Trading has launched an investigation into the off-grid market for renewables and mainstream energy in January 2011, following energy price hikes and supply issue over the winter [23].

Examples of small scale off-grid renewables are found across Scotland [24], such as remote ferry waiting rooms on the Western Iles and the Charles Inglis Clark Memorial hut on Ben Nevis using small wind turbrines. Photovoltaic (PV) installations integrated with battery are often used where only a small amount of power is required, as for lighting, maintaining power for monitoring equipment or maintaining water treatment facilities.

However, it is in developing countries where power requirements are generally low, and where rapidly improving electronic lighting and telecommunication equipment that have low power requirements and perform reliably with little or no maintenance that off-grid renewable energy is coming to its own [21].

Three examples of large scale off-grid renewable energy use with varying degrees of success are the Grameen Shakti f or renewables of Bangladesh [25], Lighting Africa [26] and Biogas for China's Socialist Countryside [27].

Grameen Shakti is a non-profit organization founded in 1996 to promote, develop, and supply renewable energy to the rural poor of Bangladesh. It has become one of the world's largest and fastest growing renewable energy companies through a system of microfinancing, training of technicians (mainly women) for installation, maintenance and repair, provision of services including buy-back. It runs technology centres for training throughout the country (see [25] for details). At the end of May 2011, Grameen Shakti had installed 636 322 solar home systems, 18 046 biogas plants and 304 414 improved cooking stoves. It also trained a total of 28 932 technicians in 46 technology centres nationwide, covering all districts. Its beneficiaries are 40 000 villages and around 4 million people [28].

What began as a grassroots endeavour to provide solar light for the rural population has now attracted the backing of the World Bank. It started by training "barefoot women engineers" for installing, maintaining and repairing solar panels, lights, telephone charging, batteries and other accessories.

Lighting Africa is now a joint World Bank and International Finance Corporation programme that aims to help develop commercial off-grid lighting markets in sub-Saharan Africa as part of the World Bank Group's wider efforts to improve access to energy [29]. It aims to provide safe, affordable, and modern off-grid lighting to 2.5 million in Africa by 2012 and to 250 million by 2030. The market for off-grid lighting products is projected to grow at 40 to 50 percent annually. In 2010 alone, the sales of solar portable lanterns that have passed Lighting Africa's quality tests grew by 70 percent in Africa, resulting in more than 672 000 people with cleaner, safer, reliable lighting and improved energy access (see [26] for details)

Provision of biogas is an important part of China's New Socialist Countryside programme launched in 2006 to improve the welfare of those living outside booming cities, which include the country's 130 million migrant workers and the rural poor. China is one of the first countries in the world to use biogas technology and it has been revived in successive campaigns by the current government to provide domestic sanitation and energy off-grid and to modernize agriculture (see [27, 30] for details). The anaerobic digester producing biogas is typically combined with a greenhouse for growing vegetables and other crops with a pigsty, so that pig and human manure can be digested while carbon dioxide generated by the pigs boosts plant growth in the greenhouse. The biogas produced (typically 60 percent methane and 40 percent carbon dioxide with traces of other gases) can be used as cooking fuel and to generate electricity, while the residue is a rich fertilizer for crops. It is an example of the circular economy that has served Chinese peasants well in traditional Chinese agriculture [31]. More elaborate models include orchards and solar panels. According to the latest update from China's Ministry of Agriculture [32], 35 million household biogas tanks have been installed by the end of 2009 in 56 500 biogas projects. This exponential growth phase that started around 2001 is set to continue, along with medium and big digesters for community and industrial use. Anaerobic digestion of organic wastes is a key renewable energy technology for a truly green circular economy off-grid that could make a real difference for improving the lives of the rural poor (See [12] for a complete list of the benefits of biogas).

Integrating sustainable farming and renewable energies in a circular economy

A model that explicitly integrates sustainable farming and renewable energies is 'Dream Farm 2' that operates according to circular economy principles (see final chapter in [10]). It is patterned after environmental engineer George Chan and the dyke-pond system of Pearl River Delta [31] that Chinese peasants have perfected over thousands of years, a system so productive that it supported 17 people per hectare in its heyday. An ideal Dream Farm 2 is presented in Figure 1.

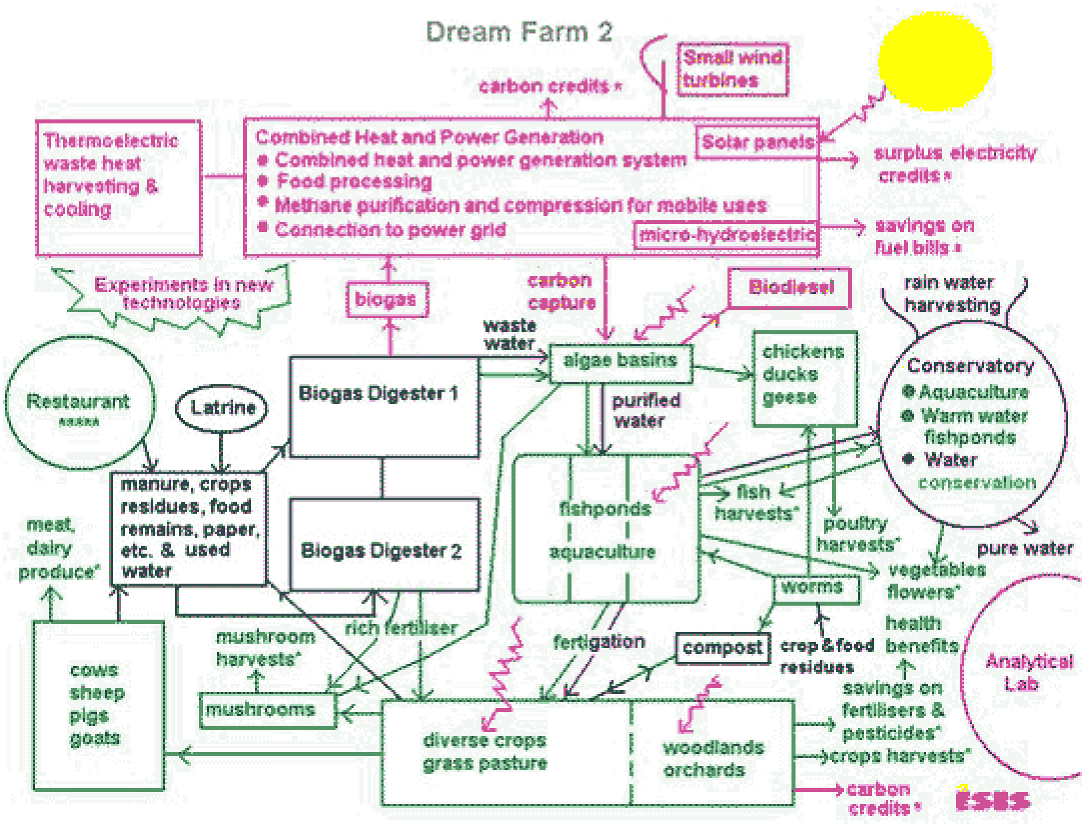

Figure 1 An integrated food and energy Dream Farm 2 that optimises the sustainable use of resources and minimises wastes in accordance with the circular economy of nature

The diagram is colour-coded. Pink is for energy, green for agricultural produce, blue is for water conservation and flood control, black is waste in the ordinary sense of the word, which soon gets converted into food and energy resources. Purple is for education and research into new science and technologies. This ideal Dream Farm is complete with laboratory facilities for education, as well as a restaurant to take advantage of all the fresh produce. It is a perfect setting for developing cottage industries such as food preservation, processing, wine and cheese making, bread-making, not to mention electronic workshops, battery charging, retailers of renewable energy components and electronic devices. The synergies between agriculture and industries are obvious especially in the case of food industries, as they are close to the source of production. Moreover, the organic wastes from these industries can go right back into anaerobic digestion to be converted into energy and nutrients for agriculture.

Some preliminary estimates, based on data and statistics made available by the Chinese government and academics, on the energy and carbon savings involved, are presented in Tables 1 and 2 [33].

	CO_2e savings	(% National)	Energy savings	(% National)
Organic agriculture				
N fertilizers saving	179.5 Mt	(2.38%)	2.608 EJ	(3.61%)
N_2O prevented	92.7 Mt	(1.23%)		
Carbon sequestration	682.9 Mt	(9.07%)		
Total for org. agri.	955.1 Mt	(12.69%)	2.608 EJ	(3.61%)
Anaerobic digestion				
Livestock manure ghg saving	70.3 Mt	(0.09%)		
methane produced	215.5 Mt	(2.86%)	3.124 EJ	(4.33%)
Hum manure methane	7.7 Mt	(0.10%)	0.112 EJ	(0.16%)
Straw methane	292.5 Mt	(3.93%)	4.234 EJ	(5.86%)
Total for AD	586.0 Mt	(7.79%)	7.470 EJ	(10.35%)
Total overall	**1 491.1 Mt**	**(20.48%)**	**10.078 EJ**	**(13.96%)**

Table 2 Green potential of Dream Farm 2

	CO_2e savings	(% National)	Energy savings	(% National)
Organic agriculture	955.1 Mt	(12.69%)	2.608 EJ	(3.61%)
Anaerobic digestion	586.0 Mt	(7.79%)	7.470 EJ	(10.35%)
Energy savings local gen.	1 287.1 Mt	(17.10%)	21.660 EJ	(30.00%)
Total	**2 828.2 Mt**	**(37.58%)**	**31.738 EJ**	**(43.96%)**

As can be seen from Table 1, the combination of organic agriculture and anaerobic digestion in China has the potential to mitigate at least 20 percent of national greenhouse gas emissions and save 14 percent of energy consumption. If Dream Farm 2 were to be universally adopted, China would mitigate 38 percent of its greenhouse emissions, and save 44 percent of energy consumption, only counting anaerobic digestion, basically because of efficiency savings arising from the possibility of using ‘waste’ heat in combined heat and power generation, and avoiding the loss in long distance transmission of electricity. A conservative allowance of 30 percent efficiency saving (out of a maximum of about 60 percent) gives the net carbon and energy savings in Table 2, which, again, is from anaerobic digestion only. The savings could be far greater as low power consuming LED lighting and other electronic devices replace conventional high power consuming models.

With the addition of solar, wind or micro-hydroelectric as appropriate, and batteries to store and maintain a steady power supply, such farms could compensate, in the best case scenario, for the carbon emissions and energy consumption of the entire nation. Surplus energy from the farm can go to supply homes and businesses in the vicinity through a ‘mini-grid’ that could eventually link up to the national grid, if necessary or desirable. This could be a model for the natural evolution of connectivity and power sharing. At the very least, such integrated food and energy farms will give food security while playing its part along with other sectors of the circular economy in cutting its own carbon footprint. Furthermore, such small scale agro-ecological farming and local renewable power generation are much more resistant and resilient to weather extremes, and indeed to earthquakes and sabotage.

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