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Renewable Energy Application for Organic Agriculture: A review

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Abstract: Agriculture is still the occupation of the majority of Thai people, despite the share of industry and services rising constantly. In terms of agricultural lands, Thailand is also one of the largest countries in the world, especially in Asia. Fruits and field crops make up for the most of vegetable products, rice being the leading crop. Currently, the market demand for organic food is increasing mainly due to consumer perceptions of quality and safety of these products. The primary goal of organic agriculture is to optimize the health and productivity of interdependent communities of soil life, plants, animals and people. Organic agriculture is expected that this requirement will continue to grow in the near future. On the other hand, energy is used in many organic agricultural inputs, including irrigation, mechanization and fertilizer. Both organic and conventional farming systems are mainly dependent on fossil energy, which is particularly crucial given rapidly growing energy costs. However, renewable resources are abundant. Many commercial technologies are available to connect these resources, and with suitable support, additional technologies could be brought to market. The aim of this research review is to investigate the utility of renewable energies for organic agricultural activities. In this concept, solar energy, biomass energy, wind energy, geothermal energy and hydropower are discussed by application. There is significant potential for organic agricultural involvement in the production and consumption of solar, wind, geothermal and biomass energy.

Keywords: Renewable Energy, Organic Agriculture, Renewable Sources, Energy System

1. Introduction

Organic agriculture refers to a farming system that enhances soil fertility through maximizing the efficient use of local resources. It relies on a number of farming practices based on ecological cycles, and aims at minimizing the environmental impact of the food industry, preserving the long term sustainability. Organic agriculture is often assumed that organic farming is synonymous with sustainable agriculture. The broad goals of sustainable agriculture include economic profitability, environmental stewardship, and community vitality [1]. The principle aims of organic production and processing as following [2,3]:

- To produce food of high quality in sufficient quantity.
- To interact in a constructive and life-enhancing way with natural systems and cycles.
- To consider the wider social and ecological impact of the organic production and processing system.
- To encourage and enhance biological cycles within the farming system, involving micro-organisms, soil flora and fauna, plants and animals.
- To develop a valuable and sustainable aquatic ecosystem.
- To maintain and increase long term fertility of soils.
- To maintain the genetic diversity of the production system and its surroundings, including the protection of plant and wildlife habitats.
- To promote the healthy use and proper care of water, water resources and all life therein.
- To use, as far as possible, renewable resources in locally organized production systems.
- To create a harmonious balance between crop production and animal husbandry.
- To give all livestock conditions of life with due consideration for the basic aspects of their innate behavior.
- To minimize all forms of pollution.

- To process organic products using renewable resources.
- To produce fully biodegradable organic products.
- To produce textiles which are long-lasting and of good quality.
- To allow everyone involved in organic production and processing a quality of life which meets their basic needs and allows an adequate return and satisfaction from their work, including a safe working environment.
- To progress toward an entire production, processing and distribution chain which is both socially just and ecologically responsible.

In addition, organic agriculture offers alternatives to energy-intensive production inputs such as synthetic fertilizers which are likely to be further limited for poor rural populations by rising energy prices. In developing countries, organic agricultural systems achieve equal or even higher yields, as compared to the current conventional practices, which translate into a potentially important option for food security and sustainable livelihoods for the rural poor in times of climate change [4].

Agriculture is a major contributor to global warming through greenhouse gases (GHG) from activities such as deforestation, soil treatment and methane emissions from livestock. It is also one of the main users of fossil fuels, thus also contributing further to GHG emissions. The cost of agricultural products is highly dependent on, and vulnerable to, fuel prices [5]. It is therefore appropriate to assess alternative sources of energy for the future of agriculture. However organic agricultural activities, such as irrigation, could be powered by renewable sources. Organic farm machinery could also be renewably powered, but the machinery would need to be adapted to use renewable electricity, instead of liquid fuel [6]. Renewable technologies are now supplying or supplementing many on-farm energy requirements, from water pumping to space heating [7]. Increasingly, farmers and ranchers are selling energy (e.g., electricity generated from wind turbines, biofuels, and products from biomass). This is contributing to greater energy security in normal and organic agriculture through increased diversity of energy sources, more self-supply of energy, and reduced environmental impact. Main renewable energy sources for applicable in organic agriculture and their usage forms presented in Table 1 [8,9].

Table 1. *Main renewable energy sources and their usage form*

Energy source	Energy conversion and usage options
Hydropower	Power generation
Modern biomass	Heat and power generation, pyrolysis, gasification, digestion
Geothermal	Urban heating, power generation, hydrothermal, hot dry rock
Solar	Solar home system, solar dryers, solar cookers
Direct solar	Photovoltaic, thermal power generation, water heaters
Wind	Power generation, wind generators, windmills, water pumps
Wave	Numerous designs
Tidal	Barrage, tidal stream

The Thailand faces a choice of energy futures. Fossil energy for mechanized agriculture has been an important driver of the "Green Revolution" of increasing farm productivity. Energy is one of the major parameters for establishing growth and progress of a country, rather than the standard of living, which depends directly upon the per capita energy consumption [10].

Renewable energy can address many concerns related to fossil energy use. It produces little or no environmental emissions and does not rely on imported fuels. Renewable resources are not finite and many are available throughout the country [11]. The sustainable energy approach promotes renewable energy in the organic agriculture sector, especially in remote or rural areas all over the world where solar energy is available in abundance. The purpose of the current paper is to present an integrated review of the methodologies, approaches and the related activities of the renewable energy application for organic agriculture. Furthermore, this article examines the domestic status and opportunities for a number of renewable energy technologies - solar, wind, geothermal and biomass.

2. Solar Energy Systems for Organic Agriculture

Solar energy is the energy derived directly from the Sun. The fastest growing type of alternative energy, increasing at 50 percent a year, is the photovoltaic cell, which converts sunlight directly into electricity. The Sun delivers yearly more than 10,000 times the energy that humans currently use [10]. Solar technologies produce electrical or thermal energy. Photovoltaic cells (or "solar cells") that convert sunlight directly into electricity are made of semiconductors such as crystalline silicon or various thin-film materials. Solar thermal technologies collect heat from the sun and then use it directly for space and water heating or convert it to electricity through conventional steam cycles, heat engines, or other generating technologies [6].

In organic agriculture, solar cells can economically provide electricity where the distance is too great to justify new power lines. Solar electric systems are used to provide electricity for lighting, battery charging, small motors, water pumping, and electric fences. The number of solar energy applications is expected to grow as new technologies increase solar cell efficiency and reduce costs. New "quantum dot" materials could theoretically more than double efficiency, converting 65 percent of the sun's energy into electricity, as compared to the best commercially available solar cells today, which have conversion efficiencies of up to 30 percent.

The first generation solar cells are based on Si wafers, beginning with Si-single crystals and the use of bulk polycrystalline Si wafers. These cells are now marketed and produce solar conversion efficiencies between 12% and 16% according to the manufacturing procedures and wafer quality. In Figure 1, one of the collections of solar modules that were used for the production of electricity in separate areas is presented. The energy storage was based on lead–acid batteries [12]. Therefore, energy storage system is an appropriate process for organic agriculture.

Figure 1. *Solar system based on Si-single crystals [12].*

3. Wind Energy for Organic Agriculture

Wind power differs from solar power in that it is available, in principle, for 24 h per day. Wind technologies provide mechanical and electrical energy for organic agriculture. Wind power grew fastest at 52% and will multiply by seven times to 2010, overtaking biopower. The reduction in greenhouse gas emissions can be achieved by production of environmentally-friendly power generation technologies (e.g. wind, solar, fuel cells, etc.). The challenge is to match leadership in greenhouse gas reduction and production of power from renewable energy resources by developing a major research and manufacturing capacity of environmentally-friendly technologies [10,13].

Wind turbines operate on a simple principle: Wind turns rotor blades, which drive an electric generator, turning the kinetic energy of the wind into electrical energy. The typical wind turbines were demonstrated in Figure 2. The wind is a renewable energy source, and windmills do not produce harmful environmental emissions. Utility-scale turbines range in size from 750 kilowatts (kW) to 5 megawatts (MW), with most turbines exceeding 1 MW. Turbines are often grouped into wind farms, which provide bulk power to the electrical grid. Small wind turbines range in size from 0.4 to 1.5 kW generators for small loads, such as battery charging for sailboats and small cabins, to 3 to 15 kW systems for a home, to those that generate up to 100 kW of electricity for larger loads, such as small commercial operations. Wind power technology is already in widespread use due to substantial progress in reducing costs for areas with consistently high wind speeds [14]. Recent' state-of-the-art wind turbines, operating in high-wind areas, can produce electricity for a few cents per kilowatt-hour (kWh), which is competitive with the cost of fossil fuel-fired plants. Accordingly, small wind systems can serve organic agriculture in traditional ways, such as using mechanical energy to pump water or grind grain. As costs decrease, small systems used to generate electricity may also become economically efficient by avoiding the expense of installing transmission wires, especially in more remote applications [15]. As technological improvements continue to increase the economic efficiency of wind energy, organic agricultural producers are likely to increase their use of wind power to lower energy costs and become more energy self-sufficient.

Figure 2. *The typical wind turbines.*

4. Geothermal for Organic Agriculture

Direct-use of geothermal energy is one of the oldest, most versatile and a common form of utilization of geothermal energy in agriculture [16]. Recently geothermal energy is utilizing in organic agriculture. There are three types of geothermal power plants are operating today: dry steam plants, flash steam plants, and binary-cycle plants. High-temperature geothermal resources (greater than 149°C) are used for power generation in organic agriculture. Utilization of geothermal energy in general can be divided into 2 types, namely utilization (indirect use) and use (direct use). Utilization of the indirect use of geothermal energy for power generation, while the direct use of the direct use of heat contained in the geothermal fluid to various fields such as conventional and organic agriculture / agro-industry, fisheries, etc [17].

Geothermal energy has many agricultural applications. Vegetables, flowers, ornamentals, and tree seedlings are raised in 43 greenhouse operations heated by geothermal energy. Forty-nine geothermal aquaculture operations raise catfish, tilapia, shrimp, alligators, tropical fish, and other aquatic species. Organic agri-industrial applications include food dehydration, grain drying, and mushroom culture. The drying of onions and garlic is the largest industrial use of geothermal energy [17].

Individual power plants can be as small as 100 kW or as large as 100 MW. The technology is suitable for rural electric mini-grids, as well as national grid applications. The heat from geothermal energy can also be utilized directly. Geothermal fluids can be used for such purposes as heating buildings, growing plants in greenhouses, dehydrating onions and garlic, heating water for fish farming, and pasteurizing milk. Generally, low-to-medium temperature resources (between 21°C and 149°C) are used. Another technology, geothermal heat pumps, can provide space heating and cooling. This technology does not require a hydrothermal (hot water) resource, but instead uses the near-surface ground as a heat source during the heating season and as a heat sink during the cooling season.

Direct or non-electric generation provides over 10,000 thermal megawatts, including geothermal heat pumps. The power from direct use systems is measured in megawatts of heat as opposed to power plants that measure power in megawatts of electricity [17]. Some geothermal projects "cascade" geothermal energy by using the same resource for different purposes simultaneously, such as heating and power. Cascading uses the resource more efficiently and improves economics. The geothermal resource base for low-to-medium temperatures is much more plentiful and widespread than the high-temperature resource base. Hence, geothermal approaches are reliable resource for organic agriculture.

5. Biorefineries for Organic Agriculture

Thailand has a great potential for use renewable raw materials in biorefineries and applicable for organic agriculture. It is one of the largest producers of agricultural and animal commodities, which produce large amounts of residues and wastes [28]. Discussion of renewable energy from biomass centers on the concept of the "biorefinery," where new technologies are being used to extract energy and other valuable products from biomass resources. Like oil refineries, biorefineries are envisioned as industrial facilities that convert a stream of raw material into a varied slate of products, maximizing value by shifting the mix of output to match dynamic market conditions. Potential biorefinery products include liquid fuels, such as ethanol and biodiesel, electricity, steam, and high-value chemicals and materials [18]. Many of these products have the potential to replace petroleum, either as a vehicle fuel or as a chemical feedstock, resulting in increased energy security and reduced environmental emissions.

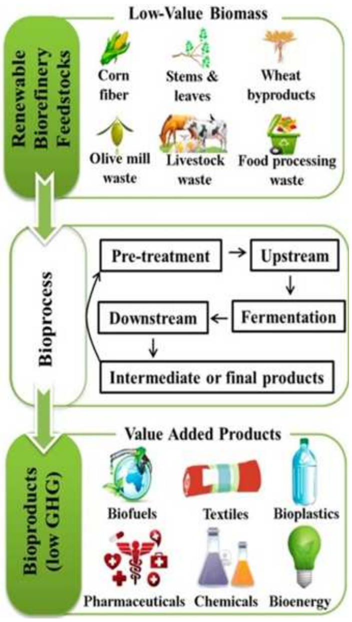

Figure 3. *Using biomass in a biorefinery concept instead of oil for producing energy and chemicals [18] via organic and conventional agriculture.*

They process corn into ethanol, corn syrup, animal feed, and other products, or transform trees into a variety of wood products, electricity, and heat. A thermochemical process (the syngas platform) involves heating biomass to turn it into a gas composed of a few basic molecules, then processing this raw material into fuels and products through chemical or biological techniques. Using biomass in a biorefinery concept instead of oil for producing energy and chemicals via organic and conventional agriculture in Figure 3.

Biorefineries use completely renewable organic agricultural products to produce a range of products for uses as wide ranging as fuel, high protein animal feed, gluten and electricity. They also have a vital role to play in reducing transport greenhouse gas emissions; from their own operations and the renewable ethanol from transport fuels they produce.

6. Renewable Energy Source Water Pumping Systems for Organic Agriculture

To meet the energy demands and reduce the environmental impact, the idea of integrating RESs such as solar photovoltaic, solar thermal, wind, biomass and hybrid forms of energy with water pumps has been proposed by many researchers around the world [19]. Comparing with conventional fuel, solar water pumping system has numerous advantages, for instance, besides of no cost for fuel and maintenance, the system it has no noise and pollution for the environment [20, 21]. Although there are solar water pumps with high capacity (10 of kW can be used), usually the pumps that are used in remote areas are small scale one (usually less than 1500 W). The main issue regarding to these systems is maintenance while at the same time 24 h electrical service is not demanded [7, 22]. Solar water pump system is generally divided into two groups; solar photovoltaic and solar thermal water pumping systems. The research developments with renewable energy source water pumping systems are presented in this section. Renewable energy source water pumping systems are classified into five major groups as follows: (1) solar photovoltaic water pumping systems, (2) solar thermal water pumping systems, (3) wind energy water pumping systems, (4) biomass water pumping systems and (5) hybrid renewable energy water pumping systems. The typical solar water pump system was demonstrated in the Figure 4.

Figure 4. *Solar water pump system, Chiang Mai Province, Thailand.*

There is a significant potential for solar water pumping in countries like Thailand which receive abundant amounts of solar radiation. Solar powered water pumps offer several advantages over their diesel and petrol counterparts. For the user, the life cycle costs are significantly lower. There is no fuel to be purchased, maintenance is greatly reduced and the system lifetime is longer. There are also significant environmental advantages. There are no pollutants, they are silent, require no fuel and contamination from spills, etc are eliminated [23]. They also contribute to energy self-sufficiency and reduce dependence on imported oil. Solar water pumping has been implemented around the globe as an alternative electric energy source for remote locations. The systems are cost effective in many remote applications especially in organic agricultural field. And this system is a mature technology to convert sunlight into electricity. Consequently, this review report concludes that renewable energy sources play a vital role in reducing the consumption of conventional energy sources and its environmental impacts for water pumping applications.

7. Renewable Energy Source as Fertilizer for Organic Agriculture

The standard biogas plant was illustrated in Figure 5. Anaerobic digestion is an optimal way to treat organic waste matter, resulting in biogas and residue. Utilization of the residue as a crop fertilizer should enhance crop yield and soil fertility, promoting closure of the global energy and nutrient cycles [24]. The digestate byproduct is the result of a mineralization process which, in general, can be used as fertilizer since it is rich in nutrients (high nitrogen-to-carbon ratio), enhances nutrient-penetration into the soil and reduces up to 80% of odours from the feedstock [25, 26]. This high content is advantageous to the organic agricultural crops as they are primarily capable of utilizing ammonium nitrogen. The slurry from the digester is rich in ammonium and other nutrients used as an organic fertilizer [24]. It is often possible to replace nitrogen from commercial fertilizer by digested slurry and thus save money [27].

Figure 5. *Biogas plant, Mae Taeng. Chiang Mai Province, Thailand [28].*

The biogas produced from swine manure and urine was used for cooking, lighting, or to maintain the temperature inside the greenhouse for optimum vegetable growth and the digestate were used as a fertilizer to replace chemical fertilizers. During winter, the low temperature and sunlight levels increases the application of chemical fertilizers. This frequent use of chemical fertilizer not only increased the cost of expenses but also decreased the vegetable quality during the winter. However, the substitution of chemical fertilizer with digestate increased the vegetable yield by 18.4% and 17.8% for cucumber and tomato respectively [29]. Consequently, Biogas is a promising renewable energy source and biogas final digestive byproduct applied to croplands as fertilizer for the organic agriculture farm.

8. Conclusion

Agriculture is the sole provider of human food. Organic agriculture is one sustainable alternative to avoid the negative environmental effects often caused by conventional agriculture. Most farm machines are driven by fossil fuels, which contribute to greenhouse gas emissions and, in turn, accelerate climate change. Such environmental damage can be mitigated by the promotion of renewable resources such as solar, wind, biomass, tidal, geo-thermal, small-scale hydro, biofuels and wave-generated power. These renewable resources have a huge potential for the agriculture industry. The farmers should be encouraged by subsidies to use renewable energy technology. Hence, there is a need for promoting use of renewable energy systems for organic agriculture, e.g. solar photovoltaic water pumps and electricity, greenhouse technologies, solar dryers for post-harvest processing, and solar hot water heaters. Clean development provides industrialized countries with an incentive to invest in emission reduction projects in developing countries to achieve a reduction in CO_2 emissions at the lowest cost. The mechanism of clean development is discussed in brief for the use of renewable systems for sustainable agricultural development specific to solar water pumps in Thailand and the world. Therefore, renewable energy technologies are being used in a variety of applications on farms, ranches and particularly in organic agriculture filed.

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