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The use of renewable energy sources in integrated energy supply systems for agriculture

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Abstract. In many sectors of the industry, for example in agriculture, many countries find alternative sources of energy as an acceptable and feasible choice, given the high energy requirements on the one hand and the negative environmental effect of fossil fuels, on the other. Sustainable agriculture is a delicate equilibrium to increase crop production and preserve economic stability while reducing the use of scarce natural resources and the negative effects of the environment. The use of renewable energy systems for sustainable agriculture, therefore, needs to be promoted. This paper is a state of art on the numerous update and feasible technologies of renewable energy applications in the agricultural sectors. It also discusses the significance of renewable energy as environmentally clean technologies and the most reliable energy source. This study covers different types of renewable energy sources like solar systems, biomass energy, and hydropower. Such forms of renewables have been proven to be suitable options in agriculture, and in particular for remote rural areas.

1. Introduction

Energy is required at all stages of agricultural products: in the cultivation of vegetables, fish, and livestock and forestry products; in post-harvest operations; in food storage and processing; in food transport and distribution; and in food preparation. The amount of energy we use in agriculture and how we use it will ultimately decide how our agricultural food systems will be able to fulfill future food security goals and achieve wider sustainability objectives in an environmentally friendly manner. In the past two decades, the production of inexpensive fossil fuels has made a major difference to feeding the planet. Nevertheless, inexpensive energy supplies tend to be getting increasingly scarcer and oil markets more competitive, and this has led to higher electricity rates. Our ability to achieve food production goals may be reduced in the future due to a shortage of inexpensive fossil energy. It



has important consequences both for the countries that profit from the original green transition and for all those countries that aim to revitalize their agriculture systems in a similar way. It will no longer be a viable choice to modernize agriculture by increasing the use of fossil fuels as has occurred in the past. Humanity needs to reconsider the role of different energy sources in developing agricultural systems.

Renewables such as hydropower, biomass, geothermal, wind and solar, offer numerous benefits and a feasible option for conventional energy sources. On one hand, they are not subject to depletion; environmental benefits can be achieved by mitigating climate change and improving health wellbeing, as provided for by the Kyoto Protocol. On the other hand, the volatility of oil demand triggering financial turbulence and confusion stems from a significant source of power [1].

Based on country, energy policies and sustainable/green energy characteristics will include practical means such as government-funded research and development, feed-in tariffs, policies promoting renewable energy output and certificates for renewable energy [2]. Through this way, policy makers will accelerate implementation, promote creativity and facilitate greater efficiency through power infrastructure. It has also sparked the attention of several small and medium-sized investment firms and, in particular, major financial groups in the renewable energy sector.

Table 1. Renewable energy sources in agricultural farms [3]

Energy source	Technology	Capacity
Solar	Domestic solar water heaters	Small
	Solar water heating for large demands	Medium-large
	PV roof grid-connected systems generating electric energy	Medium-large
Biomass	High efficiency wood boilers	Small
	CHP plants fed by agricultural wastes or energy crops	Medium
Hydro	Hydro plants in derivation schemes	Medium-small
	Hydro plants in existing water distribution networks	Medium-small
Animal manure	CHP plants fed by biogas	Small
Combined heat and power (CHP)	High efficiency lighting	Wide
	High efficiency electricity	Wide
	Householders' appliances	Wide
	High efficiency boilers	Small-medium
Wind	Plants coupled with refrigerating absorption machines	Medium-large
	Wind Turbines (grid-connected)	Medium-large

For this context, agriculture plays a crucial role as one of the most important sectors for the production of alternative energy sources among many of the productive sectors [4]. In developing economies, agriculture is increasingly regarded as a structural strategy, capable of generating food crops and addressing emerging consumer demands, delivering both public goods (agricultural landscape, biodiversity) and resources (tourist activities, power, education). This modern paradigm of farming, protecting the ecosystem and countryside balance of land for the benefit of the new trend of more environmentally friendly agricultural development, reducing the energy market and leading to effective natural resource management [5], is thoroughly embodied in the production of energy from renewable energy sources. Renewable energy sources in the agricultural industry are, in fact, an alternative source of energy that guarantees maximum energy independence and security while at the

same time having less disruptive ecological consequences. The application of renewable energy sources in agricultural industry are listed in Table 1. However the concept of renewable energy in the agriculture sector focuses on finding a balance between increasing farm productivity and promoting economic development [6, 7], while, as previously mentioned, reducing negative environmental consequences. Moreover, the use of renewable resources and natural herbicides and pesticides includes replenishing the farm land [8, 9, 10].

Thus, the main purpose of this study is to identify the possibility of using renewable energy sources in agricultural sectors.

2. Sustainable Energy Supply: Irrigation Systems

Continuity of the energy supply of groundwater irrigation systems is an important element. In the collection of groundwater pumping equipment and procedures the ineligibility of energy supply impacts farmers. Extra-large pumps are being used in the periods of electricity available to maximize abstraction and to minimize the motor burnout due to fluctuations in supply [11, 12, 13]. One common explanation why irrigation water is over applied is that farmers mount automatic pump switches to ensure that they pump water while the intermittent energy supply works. It will result in unnecessary depletion of groundwater [14].

More efficient irrigation systems for water use, however, can consume more energy. Pressurized irrigation systems, for example, such as irrigation drips, can conserve water but use energy to pressure the system [15]. Consequently, trade-offs need to be cautiously weighed and local decisions made.

Implementing efficient strategies for energy and water conservation includes an understanding of the interaction between the use of water and energy and of accountability for use of one irrigation system over another.

3. Application of Solar Technologies in Agricultural Sectors

Renewable energy is a crucial factor in steering our energy network towards efficiency and protection of supply. In the energy policy strategies, both nationally and internationally, the generation of electricity, heat or biofuel from renewable sources of energy seems to have become a high priority [16, 17].

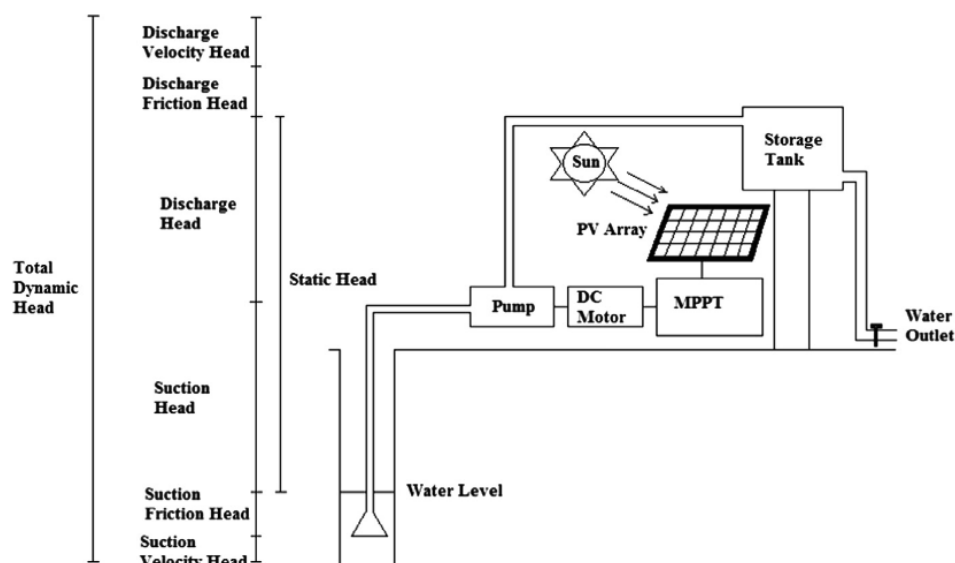


Figure 1. Schematic diagram of photovoltaic water pumping system [18]

The largest source of renewable energy is solar energy. Of example, in the process of photosynthesis, agricultural production depends on solar energy. The sun is the most cost-effective and environmentally sustainable since the large-scale use of renewable energy would not breach the rural energy policy [19]. Industrial solar energy technologies are simultaneously integrated into agricultural activities, where they are used as a direct energy source or to supplement the energy demands of farms [20]. Solar energy is one of the most used sources of renewable energy for various applications in the agricultural area [21]. For example, in the drying of crops and grain, solar energy dryers provide a more reliable and high-quality drying technique than other sources of energy. Solar electricity is also used in rural water pumps (see Figure 1). The most cost-effective water pumping system would be photovoltaic (PV) systems at places where there is no existing electricity line [22, 23, 24]. For remote livestock water source, swamp aeration, and limited irrigation systems, PV systems are cost-effective. Most water pumps currently on the market are designed primarily to be powered by a PV-panel, but any direct-stream motor pump can be worked on photovoltaic panels. A fundamental solar power supply involves a solar collector, a solar generator and turbines connected to a range of electricity consumables, for example farms and various agricultural firms [25].

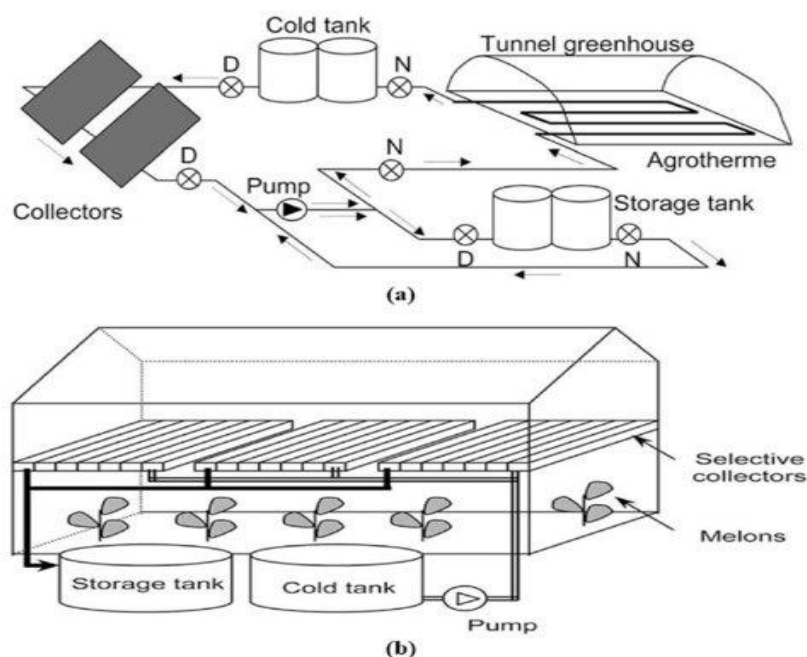


Figure 2. Schematic of the greenhouse heating system using solar flat plate collectors (a); agricultural greenhouse heated by the selective collectors (b) [31]

Additionally, the energy of the sun may be used in passive ventilation or heating, such as greenhouses, solar thermal insulation, or converted to electricity using photovoltaics (PVs) [26, 27]. Mercantile greenhouses usually rely on the solar system to supply their lighting needs, and therefore are not constructed to use the sun for heating purposes. These greenhouses rely on oil or gas heaters to sustain the temperatures needed to grow plants in the cold season. However, solar greenhouses are designed to use solar energy for both heating and lighting purposes. The solar greenhouse has thermal mass to store and collect solar thermal energy, and also the insulation to retain this thermal energy during the night and on cloudy/rainy days [28, 29]. In the Polar Regions, the solar greenhouse is designed to

maximize southern exposure to glazing. Its northern side has little or no glazed windows and is very well isolated. In order to reduce the heat loss, the glazing itself is also more efficient than single-pane glass, and multiple different products are available ranging from double-pane to "cellular" glazed windows [30]. The need for fossil fuels for heating is reduced by the solar greenhouse. An oil or natural gas heater may serve as a back-up heater or enhance carbon dioxide concentrations in order to increase crop production and plant growth [4]. The schematic diagram of the greenhouse heating system using solar flat-plate collectors and the agricultural greenhouse heated by selective collectors are shown in Figure 2.

Another possibility to use solar energy in Agriculture is irrigation systems. Solar radiation as a source of energy may be used for irrigation and is accessible at the site of operation without the use of a distribution network [32, 33]. Plant water demand and the amount of water pumped by a photovoltaic-powered water pumping system are also closely linked to average solar insolation.

4. The Role of Biomass Energy in Agriculture

The lowering of the world's reserves of non-renewable fossil hydrocarbons and the consequent increase in the cost of oil barrels following the oil crisis have formed the basis for determining and exploitation of other forms of energy production. In fact, stringent regulations on air emissions caused by combustion gasses from fossil fuels leads to the exploration of renewable energy sources. New issues for the production of bioenergy from renewable raw materials (biomass) have now arisen.

Biomass energy is energy generated from any renewable material of organic nature [34], as terrestrial plants (food, fodder agricultural crops, wood vegetation, crops for energy production, industrial plants), aquatic (algae, sea herbs) and microorganisms (fungi, yeasts, and bacteria), and also the ensemble of wastes and organic residues derived from agriculture, fish farming, forestry, municipal wastes and other residues [35]. Certainly, the agricultural products that are also nourishment source (grain, sugar beet, and oil seeds) will be main raw materials from the total amount of raw materials used to produce biofuels [36, 37], but massive research is carried on in order to raise the usage of other sources of raw materials as the residual lignocellulosic biomass [38], crops for energy production, industrial and municipal residues etc. [39, 40, 41, 42, 43, 44, 45]. Modern biofuels or bioenergy refer to biomass converted to higher value-added products and more efficient and convenient energy carriers, such as biogas, bioethanol, biodiesel and pellets [40, 42, 44, 46, 47].

On Earth, it is estimated that 171×10^9 of biomass are synthesized (containing 77×10^9 of carbon) annually by the photosynthesis process and other metabolic synthesis processes. Consequently, the biomass can be considered a very important energy resource having two substantial advantages: it is renewable, and by burning it directly or indirectly by burning the biofuels obtained from biomass CO_2 is released that comes also from atmosphere by the photosynthesis process [35]. As consequence, the CO_2 balance is zero, namely burning the biomass does not lead to an increase of the carbon dioxide concentration in atmosphere, as against burning of fossil fuels through which the carbon from lithosphere is taken to the atmosphere. Hence, bioenergy can contribute to mitigating climate change by reducing greenhouse gas emissions and diversifying energy options [35, 40, 41, 42, 43, 45]. It can also be an important part of agricultural systems. Some consider bioenergy as a way of increasing energy efficiency, encouraging agricultural growth and reducing greenhouse gas emissions [48]. The growth of the bioenergy industry was further stimulated by technical developments in the processing of biomass [49].

Multiple types of biofuels can be produced from biomass and, unlike fossil fuel (e.g. coal, oil and natural gas), biofuels contribute to the environmental conservation, and on the one hand, they generate far less harmful pollution in the atmosphere [35, 45]. On the other hand, second-generation biofuels technologies lead to the refining and cleaning of the residues from which biofuels are derived [50] (biogas, agricultural or domestic waste, bioethanol and biodiesel from agriculture, and forestry).

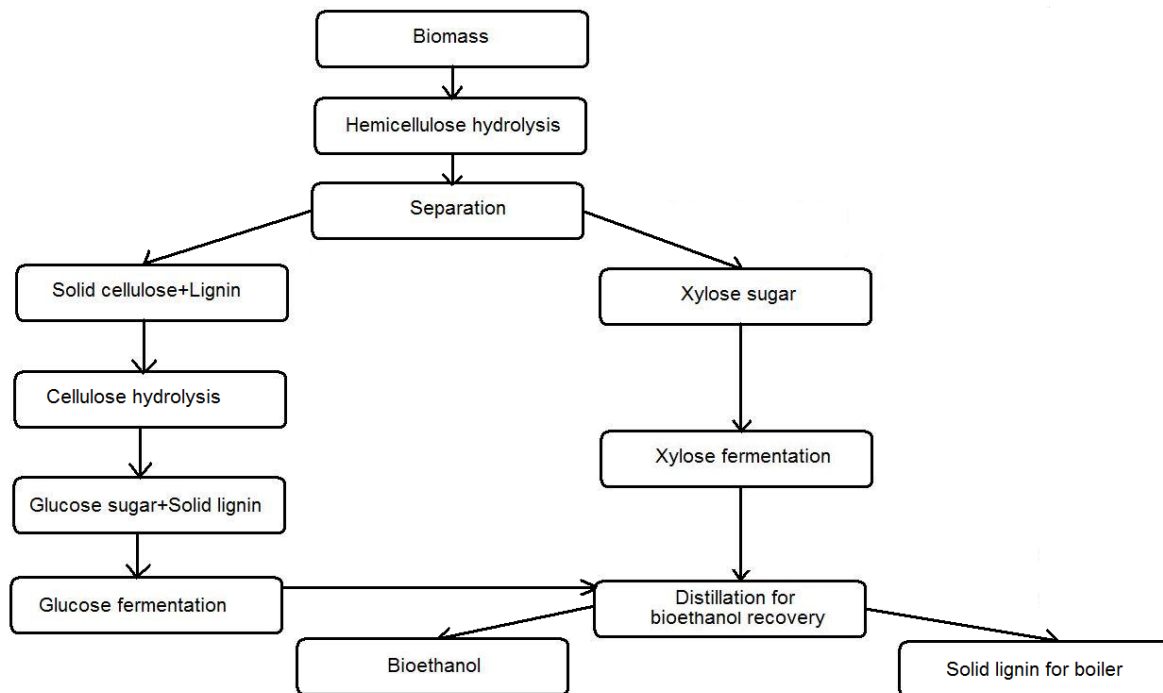


Figure 3. Bioethanol production mechanism from biomass [22]

Presently, the generation of liquid biofuels produced from agricultural feedstocks, such as bioethanol (production mechanism is shown in Figure 3) and biodiesel, is largely driven by government subsidies, tax incentives and mandates [22, 51]. Increments in global oil prices have created considerably more demand and investment in liquid biofuels. Nevertheless, though higher oil prices have raised the returns on the output of liquid biofuels, the 'threshold' at which the output of liquid biofuels is competitive has also risen along with the price of agricultural feedstocks [46]. For many developed nations, there is an immense opportunity to increase agricultural production. Liquid biofuels may be the driving force to realize this opportunity. The technological concepts that liquid biofuel production could bring to agriculture can be used to increase productivity across the entire agricultural sector, through both energy and food output [35]. In order to make sure that alternative liquid fuels add to food security by growing incomes, smallholder farmers would preferably be interested in the production of liquid biofuels [50]. Nevertheless, small holder farmers' yields are always smaller than those of big plantations and thus require more land to generate the same quantity of liquid biofuels. Out-of-grower projects are often less competitive, because yield rates are smaller and supply can be inconsistent [52, 53].

Regardless of various advantages of biomass resources, it is not easy for government and structural institutions to produce and expand community benefits. There is also a need to review current policies and institutional frameworks to further foster this renewable energy source for effective and

productive domestic and industrial usage, as well as to improve energy production capacity, call for comprehensive research and development into the economic potential of biomass and to seek more effective ways of handling agricultural waste.

5. Use of Hydropower in Agriculture

Hydroelectric power is perhaps the most rational, reliable and cost-effective renewable energy generation technology available [54]. Hydropower is the largest source of renewable energy and produces around 16 % of the world's electricity and more than four-fifths of the world's renewable energy supply [55, 56]. Worldwide installed hydropower capacity has risen exponentially since 1900, as can be seen from Figure 4. Because most developing nations have a reliable supply of electricity, hydropower has been deemed a viable supply of renewable energy to boost agricultural development in industrial plants [20, 57]. Presently, over than 25 countries around the world depend on hydroelectric power for 90 per cent of their energy production, and 12 countries depend on hydroelectric power for 100 per cent [56]. Hydro provides the majority of electricity in 65 countries and plays a key role in more than 150 countries [58]. In most developing countries, the need to improve agricultural productivity through the mechanization process along with food processing and economic benefit has been driven by major additional advances in hydropower, such as dam building [55]. In fact, the major external costs involved in the production of hydropower are the building of dams and the supply of water resources [59]. This, in addition, impacts the future production of hydropower and the reliance of nations. China, Brazil, Canada and the United States are the countries with the highest hydropower generation capacity [60] (see Figure 5).

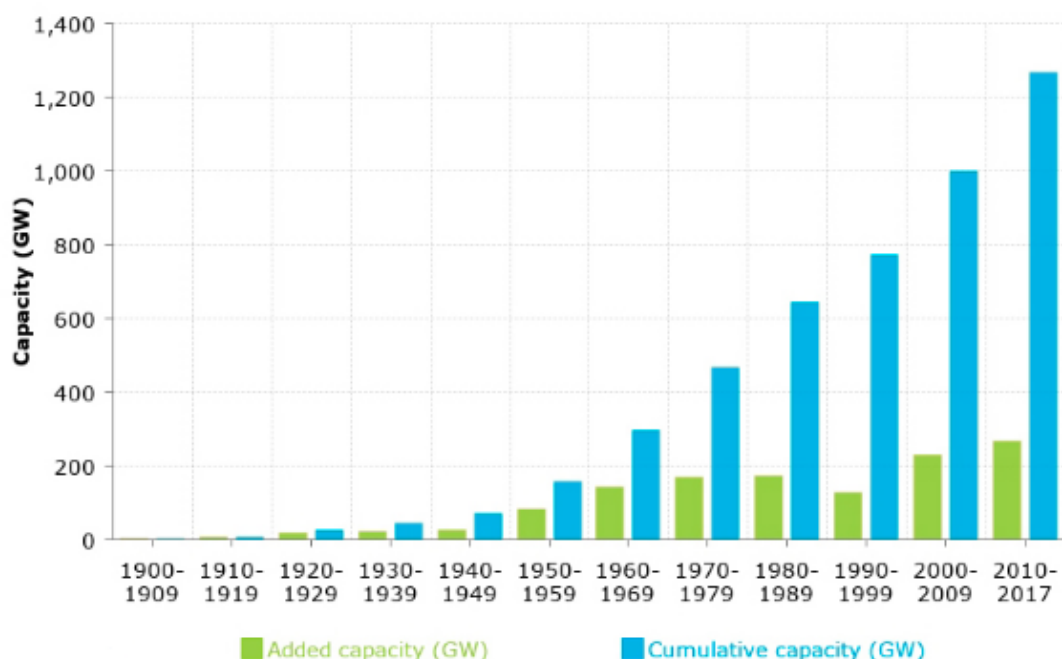


Figure 4. Hydropower installed capacity growth since 1900 (source: International Hydropower Association IHA)

Some of the main benefits of hydroelectric power is its unrivaled "load monitoring" capacity (i.e. it can follow load changes minute-by-minute) [55, 56]. In addition to grid stability and protection

facilities (spinning reserve), hydroelectric dams with large reservoirs capacity shall be used to store electricity over time, depending on the scale of the system's peaks or demand decoupled from inflows [61]. As a part of this versatility, hydroelectric power is the perfect alternative to intermittent renewable energy because, whether the sun rises or the wind blows, the volume of the reservoir can be raised at a time where there is no sunlight or wind. Moreover, where major ramps up or down supply are required due to decreases or increases in solar or wind energy, hydro will fulfill these requirements [62, 63]. Throughout agricultural systems, hydropower is being used in the following categories: field electricity for pumping water for irrigation, refining and storing of agricultural goods and for illuminating farm buildings and the environment, direct use of water for agricultural irrigation from hydroelectric dams [64] and the use of dams for aquaculture [55]. The disadvantages include: seasonal reliability, site-specific technology, irrigation needs on high-headed schemes, poor dam management leading to floods in the downstream dam sector, and lack of knowledge of the technology and how to apply it inhibits the exploitation of water resources in many areas.

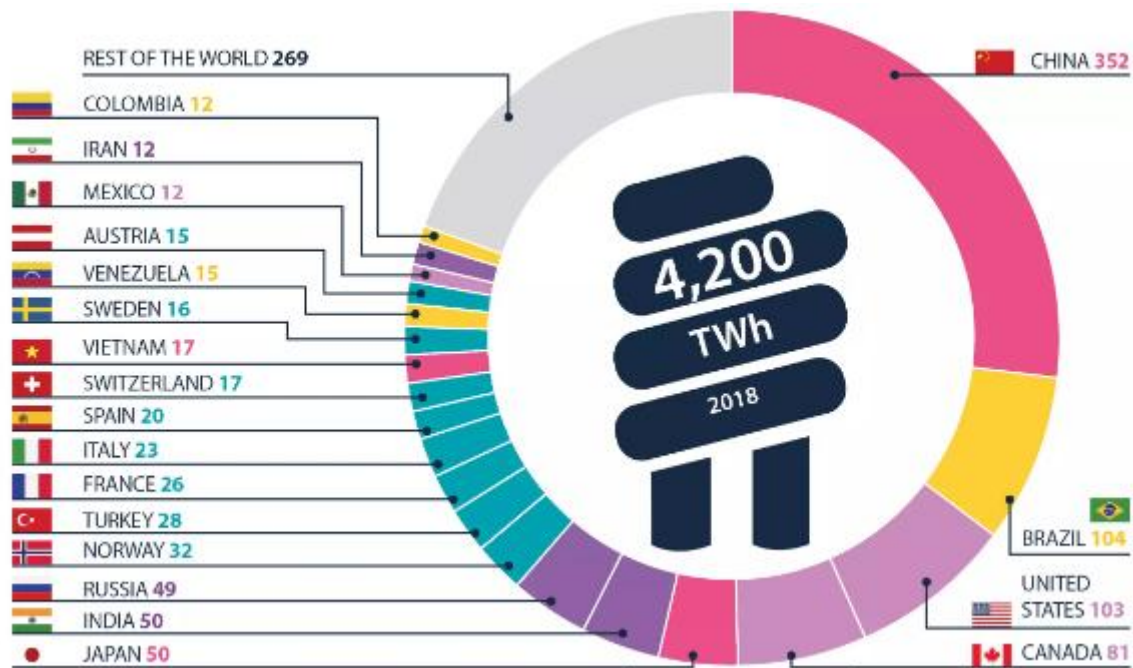


Figure 5. Hydropower installed capacity by 2018: comparison by country (source: International Hydropower Association IHA)

6. Conclusions

Current agricultural production and economic activity rely heavily on fossil fuels such as oil and coal. These energy sources are purely non-renewable can cause detrimental environmental effects. Ideally, the use of renewable resources like hydroelectric, solar power, and biomass in agricultural production should be integrated as a more sustainable and environmentally friendly energy source. This study reviewed the usage of alternative renewable energy sources such as solar, biomass, and hydropower by looking at their prospects and current applications for agricultural practices. This energy sources could serve to reduce the energy deficit various agricultural practices both in rural and urban areas and lessen the rate of environmental degradation however, adequate agricultural extension service is needed to educate, enlighten, and transfer this knowledge to rural areas for alternative energy

development, management, monitoring, and evaluation. The strengthening of local institutions, such as rural cooperatives, could also be used to promote awareness of renewable energy sources and also serve to ensure security and sustainability of rural installations for farm production and processing activities.

Conflict of Interest

The authors declare no conflict of interest.

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