Using renewable energy to meet the energy needs of smallholder farmers: Are there policies to promote adoption in Ghana?

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ABSTRACT
Integrating renewable energy (RE) technologies into agriculture can contribute to attaining sustainable production. Farmers' adoption of RE in agriculture can lead to substantial reductions in Greenhouse gases (GHG) emissions as well as providing alternative income sources for farmers, and reliable energy supplies for farms and households. Policies can facilitate, support, or encourage farmers' adoption of RE. However, it is not clear what policies currently exist which facilitate or promote the adoption of RE technologies in Ghanaian agriculture. This paper aims to identify policies in Ghana that can facilitate the adoption of RE in agricultural production. A policy review was conducted to identify such policies, evaluate their potential impact on RE adoption, and suggest paths to enhance RE adoption by farmers. These policies are focused on two aspects: 1) promoting solar energy and 2) the conversion of agricultural waste to energy. Noting limitations including the underdevelopment of the RE sector and the lack of a central policy to promote RE utilization in Ghanaian agriculture, the review suggests that policymakers need to fully implement provisions of the Renewable Energy Act-(832) (2011) through the application of, for example, policy levers such as subsidies, tax exemptions, financing, and training potential end-users in the agricultural community.

Keywords: Renewable energy; agriculture; policy; end-user adoption; Ghana
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Introduction

Energy and agriculture are interlinked sectors, with implications for sustainability at local, national, and global development levels. As such, both sectors warrant considerable attention and investment (Best, 2014). Agriculture at various scale levels has become increasingly dependent on energy, and largely been fossil fuel-based (Abaka, et al., 2017; Best, 2014). Energy is used in agriculture directly in the form of diesel/petroleum fuels, electricity, natural gas (to power farm machines, and heating, cooling, and lighting systems, etc.) and indirectly through the energy requirements involved in the manufacture of fertilizers, pesticides, and other farm chemicals (Abaka et al., 2017; Best, 2014; Clement et al., 2018; Hitaj, 2016; Sutherland, Peter, & Zagata, 2015).

There is increasingly a policy requirement in both Lower- and Middle-Income Countries (LMICs) as well as more affluent countries to replace fossil fuel consumption with renewable energy (RE) to reduce the environmental impacts of conventional energy production. Fossil fuels are known to release carbon dioxide (CO2), a Greenhouse gas (GHG), which causes global warming (Elum, Modise, & Nhamo, 2017). Agriculture is reported to contribute between 14-30 percent of global GHG due to agronomic practices, which includes fossil fuel-based energy uses (Abaka et al., 2017; Bardi, El Asmar, & Lavacchi, 2013; Lawler et al., 2013). Agricultural emissions of GHG in developing countries are considerably growing faster compared to developed countries (Tongwane & Moeletsi, 2018; Tubiello et al., 2013). Between the period 1994 to 2010, agriculture emissions of GHG were reported to be associated with an annual increase of 2.9 percent to 3.1 percent (Tongwane & Moeletsi, 2018). There are concerns about further increases occurring if there is a need to increase food production to feed the growing population.

There are potential environmental and economic gains to be made from adopting RE in agriculture including minimizing carbon emissions, thus contributing to climate change mitigation. In addition, RE adoption in agriculture can result in the improved cost-effectiveness of energy inputs, improved availability of, and accessibility to, farm energy sources, improved farm, and household energy sufficiency, and decentralized energy generation, which is of relevance to smallholder farmers in LMICs. Agricultural use of RE technologies can also contribute to the circular bio-economy, as resources for RE generation can be obtained from agricultural wastes. In this context, Fami et al. (2010, p. 704) have noted that "renewable energy and farming are a winning combination". Materials such as crops and livestock residues and bioenergy crops can be used as feedstock to generate various forms of biomass energy. This allows farmers to earn additional income by selling these materials to energy-(Behera, Behera, & Behera, 2015; Fami et al., 2010). In the most advanced case, farmers can independently generate energy (i.e., electricity and biogas) and feed into the national grid at a tariff, thus creating an additional income stream.

In sub-Saharan Africa (SSA), agriculture has long been an essential sector yet to see significant transformation compared to the Green Revolution of Asia (Feder & Savastano, 2017). Agriculture employs 65% of SSA population and contributes about 29% of the Gross Domestic Product (GDP) across the sub-region (Feder & Savastano, 2017; Gollin, 2014). Typically, the sector is dominated by smallholder farmers relying on mixed farm power including human labour, draft animals, and machines (Best, 2014; Bishop-Sambrook, 2005; Mrema, Baker, & Kahan, 2008). At present, there is relatively limited use of machinery within the smallholder sector. However, increasing productivity in smallholder agriculture may require improving agricultural production methods including mechanization (Best, 2014), thereby increasing the demand for energy within the sector (PracticalAction, 2010).

In Ghana, agriculture represents an important part of the economy. However, data on energy consumption in the sector is not widely available. Nonetheless, Ghana's Energy Commission (2019a) indicates energy, particularly fuel types consumed in Ghana's agriculture include electricity, diesel, gasoline premix and RE that is presently marginal. It is postulated that the total energy demand in agriculture is expected to increase by 2030 reaching 15,552 ktoe (kilotonne of oil equivalent) from 9,753 ktoe in 2020. A question arises as to whether RE represents a potential sustainable source of energy that can (at least partially) meet this demand.

The benefits of RE have potential to contribute to meeting the expected increase in demand for agricultural energy. The Ghanaian government together with relevant stakeholders have largely implemented policies to catalyse development and extend deployment of Ghana's RE resources and technologies. However, it is not clear what policies are available to drive RE utilisation in agriculture. This paper aims to identify policies in Ghana which have potential to act to promote RE adoption within the agricultural sector. Understanding whether these policies are effective, and what factors are linked to policy effectiveness, will contribute to the evidence base upon which future policies relevant to diffusing RE technologies in Ghanaian agriculture can be developed, strengthened, and provide information of relevance to policy development in other LMICs.

Overview of renewable energy in Ghana's agriculture

Agriculture represents an essential sector within the Ghanaian economy despite its declining growth rate (Gebrezgabher et al., 2021). The sector is predominantly occupied by smallholder farmers using an average of 2 acres of farmland for cultivation (ISSER, 2014; Tetteh et al., 2014). These farmers primarily use simple manual farm tools. At the same time, there is also a trend towards adoption of new or improved agricultural technologies applied to agronomic practices and mechanized farm tools/equipment (Kemausuor et al.,2014), which is linked to increasing demand for energy inputs such as diesel, fertilizer, and electricity (Fami et al., 2010; Kansanga et al., 2019). In view of this, there is emerging concern about smallholder farmers and the energy required to support agricultural production.

According to Best (2014), the energy needs of farmers are broadly categorised into 1) energy for production and processing and 2) energy for transporting goods to markets. Observably, many studies including Best (2014) suggest the former draws significant attention from researchers thereby putting focus largely on the energy needs for production activities in agriculture. On that score, the energy required by farmers for agricultural activities are widely seen in key areas including land preparation, irrigation, processing, and storage (Best, 2014). Land preparation in smallholder agriculture is a mix of manpower, animal, and tractor to weed, till and plough the earth. Smallholder farming is mainly rain-fed with minimal irrigation.

The irrigation practice involves the use of manually drawing water from water sources using buckets or cans and mechanically using fuel powered water pumps. When it comes to processing and storage, it is done traditionally using manual labour to harvest and dry or using machinery such as combine harvesters, threshers, and dryers. The highlight of the key areas in smallholder agriculture imply that farm-based activities are becoming energy dependent. Already, smallholders are known to lack access to modern energy forms such as electricity, petrol, diesel among others (Kaygusuz, 2011). A situation that could negatively affect food production.

RE represents a useful source for sustainably meeting farmers' energy needs (Aroonsrimorakot & Laiphrakpam, 2019). The abundance of RE resources such as solar radiation, and biomass (Bessah & Addo, 2013;

Kuamoah, 2020) can generate energy to support farm-based activities including irrigation, drying, and lighting (table 1 constitutes various RE resources and potential uses in agriculture) (Afrane, 2012; Amankwah, 2011; Arranz-Piera et al., 2016; Bayitse, Tornyie, & Bjerre, 2017; Duku, Gu, & Hagan, 2011; Kemausuor et al., 2014). Despite its relatively cheap cost, the agricultural use of energy from renewable resources is generally low in Ghana (Kuamoah, 2020). Where RE is used, it is usually in the traditional form despite the potentially increased efficiency of technologically advanced forms.

Biomass energy is known to be the oldest form of RE and is primarily utilized through the burning of wood (Elum et al., 2017). Biomass energy is used indirectly in agriculture as an energy input, through compost/organic fertilizer generated from crops and livestock residues. Solar energy is traditionally used for drying farm produce directly under the sunlight (Amankwah, 2015; Aroonsrimorakot & Laiphrakpam, 2019). While this practice incurs no costs, it tends to be less efficient and more labour intensive than mechanized solar drying and compromises the quality of farm produce by including stones, insects, and dust (Amankwah, 2015).

In some cases, RE adoption is applied on a pilot or project basis with little or no scale-up (Renewable Energy Technology Transfer Project, 2018). Nevertheless, solar-powered water pumps, mechanized solar dryers, and biofuels represent advanced forms of renewable energy that have potential to support Ghana's farm-based activities (Amankwah, 2015; Aroonsrimorakot & Laiphrakpam, 2019; Energypedia, 2018; UNDP, 2018). For example, the Energy Commission (2019) reported that about 30 solar Photovoltaic (PV) systems for water supply and irrigation had been installed in the northern parts of Ghana in pilot projects and programmes supported by donor partners and government.

In another pilot programme, farmers were assisted under an Energising Development (EnDev) programme to replace diesel generators with solar PV systems for irrigation. About 25 solar dryers were installed across the country in a pilot programme by the Ministry of Food and Agriculture, Agricultural Engineering Services Directorate (AESD). These forms of RE demonstrate the utility of RE, for example, for farms located outside local or national grid connections (Abaka et al., 2017; Bayrakcı & Koçar, 2012).

If Ghana’s agricultural sector is to increase its use of energy from renewable resources, coherent policies must be developed and implemented to drive that transition. This approach has been successful in the Global North. For example, the Renewable Energy Sources Act (REA-2004) and the EU Common Agricultural Policy-CAP have facilitated RE use in German and Czech Republican agriculture (Appel, Ostermeyer-Wiethaup, & Balmann, 2016; Frantál & Prousek, 2016).

In German agriculture, the Renewable Energy Sources Act (REA-2004) is reported to have stimulated biogas production in farms reaching a total capacity of 3543 MW from 7850 installed biogas plants by 2013 (Fachverband, 2011). Under the REA-2004, a guaranteed feed-in tariff was initiated to incentivize farmers to adopt biogas production on farms given the ready market and a fixed price to take up electricity generated for 20 years. In Czech Republican agriculture, farmers’ adoption of RE technologies was incentivized in the form of production quotas and subsidies granted by the EU’s Common Agricultural Policy-CAP and Energy policy. Farmers became encouraged to incorporate in addition to their conventional farming, bioenergy crops, biomass production and solar farms.

In Ghana, there are similar regulations such as a feed-in tariff regime and subsidies for the RE sector. So far, commercial power producers in the energy sector seem to be taking advantage of these incentives. The agricultural sector can potentially benefit from these incentives to significantly increase RE adoption. However, this may require the development of tailored incentives targeting the peculiar nature of smallholder farmers, who dominate the agricultural sector.

TABLE 1

Renewable energy resources and their potential uses in agriculture

Energy Resources	Potential Energy Usage
Small/Mini Hydropower – (water bodies including lakes, rivers etc)	Generation of electricity to power water pumps for irrigation, lighting, cooling etc.
Biomass – (bioenergy crops, agricultural and urban waste)	Generation of solid, liquid and gas energy to fuel farm machinery/ equipment, biofertilizer, heating etc.
Solar	Solar (PV) to generate electricity to power water pumps for irrigation, solar dryers, heating and supporting ventilation in greenhouse farms, lighting etc.
Geothermal	Generation of heat for greenhouse farming, aquaculture, mushroom culture, drying of crops etc.
Wind	Power generation, wind generators, windmills, water pumps etc.

Source: Bayrakcı & Koçar (2012), Owusu & Asumadu-Sarkodie (2016), and Abaka et al. (2017).

TABLE 2

Installed renewable energy generation capacity (kW)

	Off-grid		On-grid				Mini-Grid		Installed
Year	Solar	Wind	Distributed PV	Utility Solar		Hydro	Solar	Wind	
2013	-	-	495	2,500	-	-	-	-	2,995
2014	1,350	-	443	-	-	-	-	-	1,793
2015	4,003	20	700	20,000	100	4,000	256	11	29,090
2016	1,238	-	2626	-	-	-	-	-	3,865
2017	678	-	4,266	-	-	-	58	-	5,002
2018	4	-	9,441	20,000	-	-	-	-	29,445
2019	-	-	6,426	-	-	-	-	-	6,426
TOTAL	**7,273**	**20**	**24,396**	**42,500**	**100**	**4,000**	**314**	**11**	**78,614**

Source: Energy Commission (2020).

Materials and Methods

Policies promoting renewable energy development and use in agriculture

The policies were primarily obtained from online sources including Government of Ghana Ministries/Agencies websites as well as web search engines including Google Scholar. It is possible that not all relevant policy documents have been published online. A systematic online search using names of ministries, agencies and departments was employed to obtain the policies. These included 'Energy Commission', Ministry of Food and Agriculture', 'Ministry of Energy', 'Ministry of Environment, Science, Technology and Innovation'. Additionally, search terms used to search for policies included 'Renewable energy', 'energy policies in Ghana', 'agriculture in Ghana', 'agricultural policies in Ghana'. Strategic plans and frameworks that operationalized policies that impacted RE deployment in Ghanaian agriculture were also reviewed.

TABLE 3

Ghanaian policies with potential to promote renewable energy adoption in agriculture

Policy	Goal	Strategy to Promote RE adoption in Agriculture	Year
National Energy Policy	To make energy services universally accessible and readily available in an environmentally sustainable manner.	Convert agricultural waste to energy.	2010
National Bioenergy Policy (Draft)	To modernise and maximise the benefits of biomass energy utilisation on a sustainable basis.	Incentivize farmers to cultivate biofuel crops and to obtain feedstock for energy generation from agricultural waste.	2010
Strategic National Energy Plan (SNEP)	To comprehensively look at the available energy sources and resources of Ghana and how to tap them economically and timely to ensure a secured and adequate energy supply for sustainable economic growth now and into the future.	Substitution of diesel with biodiesel in agricultural mechanization, encourage more drying of exportable farm produce such as pepper with solar dryers, displace the use of diesel for irrigation with grid electricity and mechanical wind pumps.	2006-2020
Sustainable Energy for All (SE4ALL)	To ensure sustainable energy for all by the year 2030.	Establish 5000 hectares of small-scale irrigation schemes on the banks of the White and Black Volta rivers, install 2000 Poldaw windpumps to irrigate 4000 hectares of farmlands, establish 55MW[1] mini-hydro plants/ irrigation infrastructure for 1000 hectares each on the Black Volta, White Volta, Oti river, Tano river, and Pra river, establish 100,000 x 1000 kg natural convection solar dryers, and establish 5000 small-scale oil palm processing plants.	2012
National Climate Change Policy	To ensure a climate-resilient and climate-compatible economy while achieving sustainable development through equitable low-carbon economic growth for Ghana.	Seeking for low carbon emissions and aims to achieve this through the conversion of agriculture waste to energy.	2013

[1] Megawatt

National Environment Policy	To guide environmental governance, serving as reference material for research and development, guiding the country’s development along a sustainable path, and ensuring the country’s commitment to conventions, protocols and international agreements.	To promote waste-to-energy practices by converting agricultural waste to energy.	2014
Strategic National Energy Plan II (SNEP)	To provide a framework which guides decision-makers to ensure that all reasonable demands for energy in the economy are met sustainably.	Promote alternative energy forms including natural gas, wind, biomass, and solar to ensure sustainability and energy security.	2016-2030
Investing for Food and Jobs (IFJ)	To modernize Ghana’s agriculture sector to maximize contributions to the economy.	To promote the adoption of technologies, including solar and wind energy for irrigation.	2018-2021
Ghana Renewable Energy Master Plan (REMP)	To provide investment-focussed framework for the promotion and development of the country’s rich renewable energy resources for sustainable economic growth, contribute to improved social life and reduce adverse climate change effects.	To promote solar crop dryers' use by organizing training for farmers and other end-users about sustainable models for financing, operating solar dryers, and indigenize solar drying technology.	2019-2030

Results and Discussion

About 176 countries have implemented renewable energy policies (Baldwin, Carley, & Nicholson-Crotty, 2019; REN21, 2017). This indicates the role policies play in supporting the acceleration of RE resources exploitation and utilization across many economic sectors, including within agriculture (Baldwin et al., 2019). In Ghana, governments, in line with stakeholder priorities (i.e. donor/development partners), have put into place policies and legislations that aim to facilitate and increase RE exploitation and use (Gyamfi, Modjinou, & Djordjevic, 2015; Iddrisu & Bhattacharyya, 2015). The enactment of the Renewable Energy Act-(832) (2011) signified a major step in this regard.

In addition, fiscal/financial schemes may provide policy levers that aim to provide tax reductions and exemptions on RE technologies, enabling longevity and security of investments in the RE sector (National Renewable Energy Action Plan, 2015). Notable legal frameworks include the Ghana Investment Promotion Act 2013 (865), Internal Revenue Act 2000 (592), VAT Act 1998 (546), Customs Harmonised Commodity and Tariff Code Act 1993 (PNDCL 330), and the Energy Fund Act 541. For example, the Energy Fund Act 541 seeks to promote the development and deployment of renewable energy resources through the provision of financial support in the form of financial incentives, feed-in-tariffs, capital subsidies, and production-based subsidies (National Renewable Energy Action Plan, 2015).

As of 2019, a total of 78,614kW RE generation capacity was installed, an increase from 2,995kW in 2013. Table 2 depicts the total installed RE generation capacity. Although the

RE installed generation capacity is marginal compared to Ghana's total installed electricity generation capacity of 5172MW in 2019, it is a manifestation of the roles various RE policies and legislations are playing in promoting development of the RE sector. The low RE installed generation capacity has accounted for government's extension of a set goal to achieve 10 percent contribution of RE into the national energy mix from 2020 to 2030. This implies that policies should be strengthened to speed up development in the RE sector.

Different policies with potential impacts in the areas of agriculture, energy, environment, and mitigation of Climate Change are being developed in order to promote RE exploitation and adoption. At present, contributions from RE to Ghanaian agriculture appear to be minimal despite the potential of RE for meeting farm energy needs (Amankwah, 2011; Asibey, Yeboah, & Adabor, 2018; Kuamoah, 2020). This may be attributable to the cost of financing to fund RE adoption with high-interest rates for loans, insufficient incentives (tax rebate, subsidies), inadequate access to finance and long-term capital, or insufficient technical know-how for the operation and maintenance of renewable energy technologies (Mahama, Derkyi, & Nwabue, 2020).

Some specific policies that promote RE adoption in the agricultural sector can be identified. Solar and biomass energy from solar radiation and biofuels energy from agricultural wastes is included in these policies specifically in relation to the adoption of RE in agriculture. Table 3 constitutes identified policies that may facilitate RE application in Ghanaian agriculture.

The Ghanaian National Energy Policy was formulated in 2010 to enable energy services to be universally accessible and readily available in an environmentally sustainable manner (National Energy Policy, 2010). The policy does not explicitly address the promotion of energy adoption in agriculture. However, it does outline a strategy to convert agricultural waste to energy and improve the RE contribution to the national energy mix. This strategy may indirectly promote RE adoption in agriculture, as it has been reported that in addition to using RE technologies (i.e. solar, biomass, wind, etc) to support farm-based activities, biomass feedstock could be obtained from agricultural waste and used for energy generation (Fami et al., 2010).

In another example, oil palm residues from Ghanaian farms have been used to generate electricity (Asibey et al., 2018). Generation of energy at the farm level can serve farm-energy needs and facilitate a potential scale-up to rapidly accelerate the rural electrification programme that aims to extend electricity to rural communities not connected to the national grid. The National Bioenergy Policy (Draft) was formulated in 2010 with an over-arching goal to modernize and maximize bioenergy's economic and environmental benefits in a sustainable manner. In 2015, biomass (firewood, charcoal, and agricultural residues) became the second most used energy in Ghana (40 percent), after petroleum products (gasoline, diesel, LPG, and jet fuel) (47 percent) (Energy Commission, 2019).

As for the 2010 National Bioenergy Policy, the policy action's focus is not the accelerated adoption of RE in agriculture per se. There is, however, a future strategy being implemented to incentivize farmers to cultivate biofuel crops and industry players to obtain feedstock for energy generation from agricultural waste. This will take the form of fiscal incentives and favourable pricing mechanisms. As of October 2014, a Feed-in tariff of 56.0075 GHp/KWh[2] and 59.0330 GHp/KWh was set for biomass from enhanced technology and biomass from plantations feedstock respectively (Netherlands Enterprise Agency, 2016). These are beneficial and can indirectly promote RE adoption in agriculture.

A study by Arranz-Piera et al. (2016) found that energy could be generated to capacities of 600kWe[3] and 1MWe[4] based on biomass from crop residues. In one of the field-case areas, Lawra district (now Lawra Municipal), it was estimated that crop residues from a minimum total of 280 small farm holdings with an average farm size of 1 hectare could enable an energy generation capacity of 600kWe. However, the energy generation capacity of 1MWe required crop residues from a minimum of 467 farms with an average farm size of 1 hectare, suggesting that farmers can potentially increase income generation up by 29US$ to 64US$ per tonne of crop residues sold. This means a significant increase in income for farmers or households with large farm sizes.

Policies including the National Energy and Bioenergy policies were supported by a Strategic National Energy Plan I, SNEP I, (SNEP 2006-2020). One of the plan's objectives was to increase access to modern energy in the agricultural and fisheries sectors. The SNEP 1 aimed to encourage the substitution of diesel with biodiesel in agricultural mechanization, encourage more drying of exportable farm produce such as pepper with solar dryers, displace the use of diesel for irrigation with grid electricity and mechanical wind pumps, and encourage large-scale commercial poultry farmers to meet at least 10 percent of their electricity needs from biogas, using the droppings from the birds. The SNEP I has been revised to a second iteration, Strategic National Energy Plan II (SNEP, 2016-2030) which acknowledges agriculture as one of the energy demanding economic sectors. However, overall, this framework does not focus on the extensive utility of renewable energy in agriculture. Rather, there is a policy objective to consider alternative energy forms including natural gas, wind, biomass, and solar to ensure sustainability and energy security.

The Government of Ghana in 2012 implemented a United Nations (UN) led initiative known as the Sustainable Energy for All (SE4ALL). Key among this initiative's objectives was to ensure universal access to modern energy services, double the rate of improvements in energy efficiency, and double the share of RE in the global energy mix. A Country Action Plan (CAP) for Ghana was developed to promote RE utilization in agriculture by 2030. For instance, the CAP sets to conduct a feasibility study and implement a total of 5000 hectares of small-scale irrigation schemes on the banks of the White and Black Volta rivers in the Northern, Upper East and Upper West regions; conduct a feasibility study and install 2000 Poldaw windpumps to irrigate 4000 hectares of farmlands in Central, Greater Accra and Volta regions; and conduct a feasibility study and establish 55MW[5] mini-hydro plants/irrigation infrastructure for 1000 hectares each on the Black Volta, White Volta, Oti river, Tano river, and Pra river.

Other strategies in the CAP are to establish 100,000 x 1000 kg natural convection solar dryers for cassava, maize and vegetables for small-farmer cooperatives in all regions, and to conduct a feasibility study and establish 5000 small-scale oil palm processing plants in

[2] GHp/KWh – Ghana pesewas per Kilowatt-Hour
[3] Kilowatt-electric
[4] Megawatt electric
[5] Megawatt

oil palm producing areas in Central, Western, Eastern and Ashanti regions. Implementing these strategies has the potential to significantly support the government's flagship programme of constructing irrigational dams in the northern part of Ghana, thereby, increasing RE adoption in Ghanaian agriculture.

A Ghana Renewable Energy Master Plan (REMP) (2019-2030) has been implemented with the goal "to provide investment-focussed framework for the promotion and development of the country's rich renewable energy resources for sustainable economic growth, contribute to improved social life and reduce adverse climate change effects" (Energy Commission, 2019, p. iv). The REMP has set strategies and targets to scale-up utilization of solar and wind energy technologies for agricultural purposes including irrigation and crop drying. Strategies are being put into place to promote solar crop dryers' use by organizing training for farmers and other end-users about sustainable models for financing, operating solar dryers, and indigenize solar drying technology.

As of 2015, there were 70 solar crop dryer units, and it is targeted that 150, 400 and 700 units are to be installed by 2020, 2025 and 2030 respectively. Strategies to promote solar irrigation systems include partnering with and incentivizing financial institutions to develop cost-effective financing packages to promote solar irrigation, building the capacities of farmers and other end-users about the installation, operation and maintenance of solar irrigation facilities. The ambition is to install solar irrigation systems be installed over 6150, 26150 and 46150 hectares by 2020, 2025, and 2030. Also, there are strategies to promote wind energy irrigation systems by reviewing the existing installations' status and conducting studies to identify potential areas and niche markets for implementation. By the years 2020, 2025, and 2030, it is targeted that 35, 65 and 100 wind irrigation systems are to be installed respectively.

The Ghanaian government response to Climate Change included the formulation of the National Climate Change Policy (NCCP) in 2013. The policy aims to promote effective adaptation, mitigation, and social development. The NCCP acknowledges that agriculture and energy-sector-related activities are among the factors that directly and indirectly account for the changing climatic conditions. Between 1990 to 2000, the agriculture sector contributed about 44 percent of Ghana's carbon emissions (MESTI, 2015). Therefore, the NCCP advocates for low carbon emissions and aims to achieve this through the conversion of agriculture waste to energy.

The National Climate Change Policy Action Programme and Implementation (2015-2020) that operationalizes the NCCP strategically advocates promoting and using more efficient solid and liquid biofuels. To that effect, agriculture may provide feedstock, including bioenergy crops and crops and livestock residue, to generate more efficient biofuels. Biofuels energy may be utilized in support of farm-based activities, including powering farm machinery.

The National Environment Policy was formulated in 2014 to guide environmental governance, serving as reference material for research and development, guiding the country's development along a sustainable path, and ensuring the country's commitment to conventions, protocols and international agreements.

One proposed approach to achieve the stipulated policy goals is to promote waste-to-energy practices (and achieve a more circular bio-economy) by converting agricultural waste to energy. Though this approach primarily aims to improve environmental sanitation, it can also promote RE's adoption in agriculture. Otchere-Appiah and Hagan (2014) identified the potential generation of electricity from maize residue in rural agricultural areas in the Brong-Ahafo Region of Ghana (now Ahafo, Bono and Bono East regions). Based on estimates of annual maize residue production of 329,059 tonnes, electricity could be generated to a capacity of about 494GWh[6]. This energy can be beneficial for meeting farm energy needs and contribute towards improving rural electrification.

Investing for Food and Jobs (IFJ) (2018-2021) is currently one of Ghana's agriculture sectors' main policy frameworks. The framework has an overall goal of modernizing Ghana's agriculture sector to maximize contributions to the economy. Though RE utilization in agriculture is not central to this policy's goal, the issue of low adoption of technology among smallholder farmers is acknowledged within the policy to be affecting efficiency and yields. Therefore, there is a strategy to promote the adoption of technologies, including solar and wind energy for irrigation.

Notably, this paper finds no Ghanaian policy with an over-arching goal to promote RE adoption in agriculture. The current policies only attempt to state in-part the possible integration of RE technologies in agriculture without explicitly demonstrating how these technologies may be practically realised. Perhaps, supporting policy frameworks such as action plans for the various policies may clearly outline strategies leading to the direct application of RE in agriculture.

Nevertheless, these identified policies are capable of somewhat addressing the issue of promoting RE adoption in agriculture. Just that, the impacts of these policies are limited because RE adoption in the agricultural sector is not the primary focus. For example, the National Environment Policy has, as one of its goals, improved sanitation through the conversion of wastes from agriculture to energy. However, Municipal waste has been found to constitute the predominant feedstock for Ghanaian energy generation (Daniel, Pasch, & Nayina, 2014). The authors reported that many of the waste-to-energy projects in Ghana focused particularly on improving urban sanitation hence the dependence on municipal waste as feedstock for generating energy.

The policies that promote RE technologies in agriculture predominantly focus on biomass and solar energy, perhaps indicating more investments and exploitation. As noted in the Ghana Renewable Energy Act, 2011, (Act 832), adoption of approaches to exploit RE resources including wind, geothermal, and ocean as energy sources are not a policy priority. However, the policy consideration of these alternative sources is required.

Overall, it is worthy to note that the policies reviewed above are potentially capable of significantly accelerating development of Ghana's RE sector upon which the agricultural sector can leverage on to serve farm energy needs. Nonetheless, this paper proposes that for Ghanaian agriculture to see considerable contributions from RE sources, an agricultural sector led policy tailored with incentives including subsidies, tax reduction or exemption, financing and training on RE technologies should be implemented to suite the peculiar nature of smallholder farmers. Although there

[6] Gigawatt hours

are existing institutional frameworks as well as policy and legislative incentives that give subsidies and tax reduction on RE technologies, the application of these incentives appear not to have significant impact on the agricultural sector.

As the dominant group in the agricultural sector, smallholder farmers are typically low-income earners and are widely constrained with adopting new agricultural technologies that have associated cost. Farmers may be provided with incentives in the form of finance schemes through cooperative membership, start-up loans, and microfinancing to support the adoption of RE technologies. RE technologies are arguably seen to have high cost in the initial or setup stage although it has a long-term cost effectiveness. In view of that, a policy framework that seeks to drastically reduce the initial high-cost component of RE technologies is a major boost towards smallholder farmers' adoption of RE technologies.

Agricultural activities vary among smallholder farmers and is by far determined by different production methods, geographic location, inter alia. For that matter, a policy may precisely promote the adoption of RE specific technologies to serve farm-based needs. For instance, a policy may target farmers in Northern Ghana to adopt solar technologies due to the abundance of sunshine. The solar technologies may include solar powered water-pumps for irrigation and solar dryers for drying crops. This move may be feasible as Mensah, Oyewo, and Breyer (2021) in their study found that many of Ghana's solar PV installations were in the north.

Other studies have even indicated that more solar PV installations could be established in northern Ghana in future due to the abundance of sunshine (Agyekum, 2021; Quansah & Adaramola, 2018). Also, a policy may consider developing and building the capacity and knowledge of smallholder farmers on RE technologies possibly through agricultural extension services and programmes. Such capacity building can involve educating farmers on the potentials for cultivating bioenergy crops especially on lands that are less suitable for food production. By doing so, the risk of using arable land for bioenergy cultivation will be minimised.

Conclusion and Recommendation

The research is based on a review of policy documents published online. Therefore, it may have failed to identify other policies that may be in place but not published online. Nevertheless, this research forms a basis for future research that may involve engaging of experts and stakeholder institutions via interviews to obtain information on any other relevant policies that may be being considered, developed or in place, as well as other associated issues.

At present, the integration of RE into Ghana's agriculture is low, in part because of the underdevelopment of the RE sector (Amankwah, 2011; Asibey et al., 2018; Kuamoah, 2020). Nonetheless, various policies include interventions and strategies that can indirectly promote RE adoption in agriculture. These include the National Energy Policy, National Bioenergy Policy, National Climate Change Policy, National Environment Policy, Strategic National Energy Plan I, Ghana Renewable Energy Master Plan, and Investing for Food and Jobs Policy. These policies promote RE adoption in agriculture pertaining to solar energy from the sun and biomass energy by converting agricultural and other waste to energy, available to the circular bio-economy within Ghana.

The energy generated can support farm-based activities and support other energy needs, including rural electrification. However, to fully realize the potential of RE adoption in agriculture, this paper recommends that policymakers must implement all provisions of the Renewable Energy Act-(832) (2011) to accelerate the sector's development. Government and its stakeholders should implement a policy with an over-arching goal to directly promote RE integration into agriculture.

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