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A comprehensive method to assess the feasibility of renewable energy on Algerian dairy farms

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ABSTRACT

In order to achieve self-sufficiency, increasing national milk production is a priority of the Algerian government. This will increase on-farm demand for electricity supplied primarily from fossil fuels, which contribute to the emissions of greenhouse gases and accelerate climate change. Hence, there is a need for promoting the use of renewable energy and low carbon technologies for the sustainable development of agriculture and to reduce environmental load. In this light, this study proposes a simple and comprehensive method to assess the feasibility and the impact of replacing the existing conventional systems with renewable energy. First, we estimate the electricity consumption of modern farms in major dairy regions. Then, we identify the optimal system for satisfying farm-related electrical energy needs. The proposed method called for generalizing a successful experience conducted in a typical farm with the same characteristics and meteorological conditions to demonstrate the benefits of renewable energy utilization. The hybrid optimization model for electric renewable (HOMER) software, developed by the U.S. National Renewable Energy Laboratory, was used to determine the optimal system configuration in terms of net present cost, carbon mitigation, and renewable fraction. Renewable system components characteristics, prices, and electricity tariffs are modeled according to the Algerian market. Detailed sensitivity analyses of solar and wind resources, economic parameters as well as farm load variation on the optimal renewable energy system configuration are performed. In addition to the feasibility study focusing on the production of on-site clean energy to satisfy the load demand, this study investigates the impact of the introduction of grid-connected green energy on the energy balance of agricultural farms and the national power grid. We found that on-farm electricity consumption varies from 330 to 566 kWh/cow/year. The simulation results helped to determine the technical feasibility and economic viability of the proposed systems. We conclude that the proposed systems could improve the reliability of the utility grid during peak load periods by generating 136 GWh/year while decreasing greenhouse gas emissions by 80 million tons. This is one of the first studies that provides a clear approach for estimating electricity demand and determining the optimal renewable energy system for Algerian dairy farms. This approach is expected to contribute to the promotion of green technologies and sustainable development of the agriculture sector.

1. Introduction

Agriculture constitutes an important sector of the Algerian economy. On average, it represents 10% of Algeria's GDP. Approximately 21% of the Algerian population is engaged in the agriculture sector. National agricultural production accounts for 70% of available food. Despite this, a large shortage of milk and dairy products was recorded in recent years (Benaïssa, 2012). Algeria is the largest dairy consumer in the Maghreb region, with a production of more than 5 billion liters/year. Currently, domestic production accounts for less than 60% of nationwide demand, with the balance being imported. Annual imports of milk and dairy products totalled $1.26 billion in 2013 (Algerian Foreign Trade Statistics, 2013). Enforcement of food safety and the reduction of imports are two of the main priorities of the national economic and social development program. Algeria plans to rebuild the dairy sector to limit the effects of fluctuating milk prices on the worldwide market. The proposed plan comprises importing heifers and modernizing Algerian farms

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to increase local milk production (Agriculture Department, 2012). However, the plan will have consequences for national energy consumption, making farming more energy intensive.

Algeria's electricity demand is growing rapidly at an average annual rate of 9.5% in the last five years. To keep pace with projected economic growth and demographic development, electricity production must almost double in the next decade (Bélaïda and Abderrahmani, 2013). In 2013, almost 60 TWh was generated. Over 99% of that production was based on natural gas, with the balance originating from diesel plants and renewable energy. The share of renewable energy in the national energy mix is less than 0.6%. The amounts and share of electricity generation in 2013 from different sources (Energy, 2014) is summarized in Table 1. With the growth in electric demand and the rapid depletion of fossil fuels, the Algerian government has realized the importance of renewable energy to extend fossil fuels reserves and promote sustainable solutions for combating global climate change, especially greenhouse gas emissions (Himri et al., 2009). Currently, Algeria anticipates the substitution of fossil energies with other sources. National energy and environmental policies reflect the objectives of energy efficiency and renewable energy production. Abundant solar energy potential and the steady development of renewable energy technologies, together with decreasing costs, tend to favor the continued growth of photovoltaic use. The goals of the Algerian policies are to achieve 37% of total energy use for solar energy and 3% for wind energy use by 2030 (Boudghene Stambouli et al., 2012).

Nerini et al. (2014) proposed techno-economic, environmental, social, and institutional criteria to assess and identify the best solutions for electrification of the Brazilian Amazon regions. According to the multi criteria analysis index, biomass and PV systems were the most suitable for application in isolated regions. Although diesel generator systems registered the lowest scores, these systems are the most convenient short-term solutions to meet the governmental program goals. Adaramola et al. (2014) investigated the possibility of using hybrid energy systems for residential applications in rural and semi-urban areas of northern Nigeria. A PV/diesel/battery system was found to be the most sustainable and cost effective system for improving the living standard of rural inhabitants in that region. The financial viability of renewable energy in rural India was studied by Kobayakawa and Kandpal Tara (2014). Their study identified economically viable systems that balanced financial viability and affordability. Fabrizio (2011) investigated the feasibility of a multi-energy system in a hospital facility under Italian climate. The study found that the solar PV was more economically convenient than a solar collector plant needing a back-up gas boiler and hot water storage. Cucchiella et al. (2013) analyzed the economic and environmental performance of building integrated photovoltaic (BIPV) systems in Italy. The study identified the actions necessary at the national scale for the installation of PV systems appropriate to meet the needs of users and also comply with the limits imposed on CO_2 emissions under the Kyoto Protocol. It identified three scenarios to optimize system production capacity, return on investment, and the static consumption self-sufficiency. The study determined that the optimal BIPV system had the potential to mitigate 8.5 tCO_2 per installed kWp and generate a net cash flow of €2.000 per installed kWp. Glassbrook et al. (2014) assessed the economic feasibility of small wind turbines in Thailand. The study concluded that wind turbine installation in rural communities had the potential to significantly decrease Thailand's greenhouse gas emissions and help reduce the effects of global warming. However, these systems could not be used as the primary source of electricity production without government incentives.

Many researchers have investigated the use of renewable energy in agriculture. Bayrakcı and Koçar (2012) investigated the potential of Turkey's agriculture industry to use different forms of renewable energy. A similar study was performed by Chel and Kaushik (2011) to promote the use of renewable energy in India for sustainable agriculture development. Bardi et al. (2013) examined the possibility of a transition under which farms switch their energy use from fossil fuels to renewable electricity in a paradigm called “turning electricity into food.” The study showed that putting electricity to work at producing food was possible in several sectors of the agricultural industry, such as powering agricultural machinery, producing nitrogen-based fertilizers, and irrigation of crops. Santafé et al. (2014) developed an innovative photovoltaic floating cover for irrigation reservoirs to reduce evaporation of water and generate renewable electricity. Beckman and Xiarchos (2013) identified the technical and economic factors influencing the adoption of renewable energy on farms in California. The feasibility of using photovoltaic energy in Tennessee's poultry industry was studied by Bazen and Brown (2009). Recent studies examined the feasibility of anaerobic digesters in the cattle industry to produce on-farm electricity and reduce greenhouse gas emissions from livestock operations. One study concluded that 500 cows were considered to be the minimal herd size to support a profitable digester (Binkley et al., 2013). In the Algerian context, few studies have examined on-farm renewable energy use. Hamidat et al. (2003) analyzed the feasibility of a photovoltaic water pumping system for crop irrigation in the Algerian Sahara regions. This work showed the potential of photovoltaic pumping to cover water needs and its contribution to sustainable development of the local farming. Nacer et al. (2014) demonstrated the feasibility of a grid-connected photovoltaic system at Mitidja's farms. However, to date, no detailed study has been undertaken to evaluate the optimal renewable energy configuration for sustainable farming in Algeria.

Farmers play a very particular role in the development of renewable energy in Algeria. Usually located close to major residential areas, agriculture, specifically dairy farms, could sustainably produce their own energy and potentially export green electricity to the power grid during periods of peak demand and play a significant role in reducing environmental pollutants as well as lowering farm production costs.

This study proposed a method to assess the feasibility of renewable energy use in the Algerian dairy farming industry. First, we estimated the electric power consumption of a typical dairy farm. That consumption was considered to be a model of energy use efficiency. The next step was a technical and economic feasibility study using specialized software to identify the optimal system configuration according to specifications of location. An impact analysis was then conducted to evaluate the benefits of introducing the optimal system into the dairy farming process with a sensitivity

Table 1
2013 electricity generation in Algeria by energy source (in bold) and respective technologies (Energy, 2014).

Type of equipment	Production (GWh)	Share %
Gas plants	**59,333**	**99.06**
Of **which**		
Steam turbine	9582	15.99
Combined cycle	30,255	50.52
Gas turbine	14,829	24.76
Hybrid site	924	1.54
Auto-production	3742	6.25
Diesel	**227**	**0.38**
Renewables	**330**	**0.55**
Hydraulic	99	0.16
Solar	231	0.39
Total	**59,890**	**100.00**