AGRICULTURE AND AUTONOMOUS POWER SUPPLY

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Summary

This contribution is meant to be a brief guide to electrical energy generation from renewable sources, with special reference to powers ratings relevant to farms which are rarely above 300–400 kW (mostly under 50–100 kW in the developed countries and much less in the developing countries).

The main objective is to provide an analysis of the problems concerned with the supply of electricity which is an important element of energy self-sufficiency. The following subjects are discussed:

1. renewable energy sources considered to be those most best suited for power supply;
2. relevant conversion technologies to electrical energy;
3. basic data needed for technical evaluations;
4. application limits of sources and technologies.

Special attention has been paid to problems that may arise as a result of the adoption of renewable sources. In fact, one of the reasons why these sources are not fully employed is that farmers know little about their practical application and the problems relevant to

the integration between the different sources (renewable and non-renewable) representing the most common case in the practice.

1. Introduction

The purpose of this chapter is to provide basic indications for an analysis of the problems concerned with the supply of power to farms, especially from renewable sources.

In the first instance, it should be noted that electrical energy is—from a general point of view—the most effective and versatile energy carrier. In fact, electricity consumption is increasing everywhere in the world and in all the sectors. However, it requires expensive and some times high-tech plants, difficult to analyze in a few pages, due to the extreme variability from one situation to another (the spectrum of socioeconomic situations and of size of plants considered in this report is too broad). Consequently, the aim of the chapter has been restricted to provide the reader with the necessary elements for an initial evaluation comparing alternative technologies that are familiar.

Electricity is an essential element in all productive processes. In both agricultural and manufacturing industries, however, its irreplaceable importance is often underrated. Indeed, in industrialized countries it may be observed that electricity:

- often does not have a significant impact on production costs;
- at present is easy to find;
- does not pose important technical problems.

On the other hand, electricity becomes a priority when one of these conditions no longer holds, which is the typical situation in developing countries. The question of power supply and the choice of related technologies is generally tackled using quite different criteria, depending on the existence or absence of grids for the continuous supply of energy (Table 1). In the latter case, the main problem concerns the technical aspects associated with energy self-sufficiency (i.e., essential requirements will have to be met even at high costs). In the former case, however, the following factors are important:

- the price of electricity from the grid;
- the convenience and reliability of the service;
- the risks connected with individual energy production.

Technical and/or economical item	Presence of the grid		Absence of the grid	
	Reliable supply (1)	Unreliable supply (1)	Double plant (2)	Single plant (2)
Cost/technical constrains for farm connection to the grid	—	—	•••	••••
Cost of the electrical energy from the grid	••••	••	••• (3)	•••• (3)
Cost of electrical energy from generators-sets fed by fossil fuels	•••	••••	••••	••
Possibility to rationalize electrical energy needs	••	••	••••	••••

Patterns of electrical needs (throughout the year and the most representative days)	•	••	•••	••••
Type and characteristics of renewable sources available	•••	•••	••••	••••

Notes:
1: in terms of the presence of problems related to the quality and continuity of electrical energy supply
2: double plant: generator-set fed with fossil fuels and plant based on renewable sources (the basic device may be the same: i.e., reciprocating engine fed by diesel fuel and/or vegetable oil). Single plant: plant based only on a renewable source
3: if the connection to the grid could be considered

Table 1. Basic information useful to select the strategy and the type of an autonomous electricity supply. The greater the number of bullets, the greater the knowledge is of the relevant information.

Although food production requires relatively little energy, agriculture in the developed countries is critically dependent upon fossil energy. In developing countries conventional energy consumption is much smaller, but there is a need to modernize the sector, increasing the use of more advanced (and energy-intensive) technologies.

In addition, there is increasing concern in relation to the environment and, in particular, on the long-term effects due to the *global warming*. In fact, agriculture accounts for about one-fifth of the projected *greenhouse gases*, producing about 50% and 70%, respectively, of overall methane, nitrous oxide (N_2O) and carbon dioxide emissions. Promising approaches for mitigation include more efficient conventional technologies and a larger utilization of the renewable sources.

Taking into account these issues, the *autonomous power supply* should primarily deal with environmentally sound technologies and energy sources. In particular, the agricultural sector offers the most concrete opportunity for using renewable sources. In fact:

- farm power requirements are generally moderate and they sometimes match the availability of renewable sources;
- electricity could be required in remote areas (easy to find also in grid-connected farms) where it would be expensive to run cables from a main power supply;
- farmers are normally open to renewable sources and tolerate breaks in power continuity better;
- some renewable sources (i.e. biomass) are unique to agriculture.

On the other hand:

- Most of the renewable sources (i.e. solar and wind energy) are intermittent and the relevant energy should be stored in order to match the requirements. Consequently, plants are expensive and often need attention.

- Some important farm operations are seasonal or typically 20–60 days per year (i.e. drying in mild-climate countries). Then, it is necessary to reduce investments for energy plants and structures.
- Some applications need a reliable power source. In this context, a double plant (conventional and renewable sources) could be required.

2. Power Production and Aspects Concerning the use of Renewable Sources

2.1 Basic Concepts

From a general point of view, the user is always willing to evaluate various energy plant designs and the final choice is not always the most economical or rational (indeed, expensive features, such as increased functional reliability, may be considered useful). When connection to a grid is possible, the supply of electricity is usually based on strictly economic considerations, while in other cases a wide range of situations may exist, which have to be examined on a case-by-case basis. This fact is extremely important when it comes to selecting energy conversion technologies. In all cases, the supply and production of power pose two types of problems (Figure 1):

- possible modification of existing energy plants;
- choice of the most suitable source and energy plants (in case of the absence or complete reconstruction of the plants themselves).

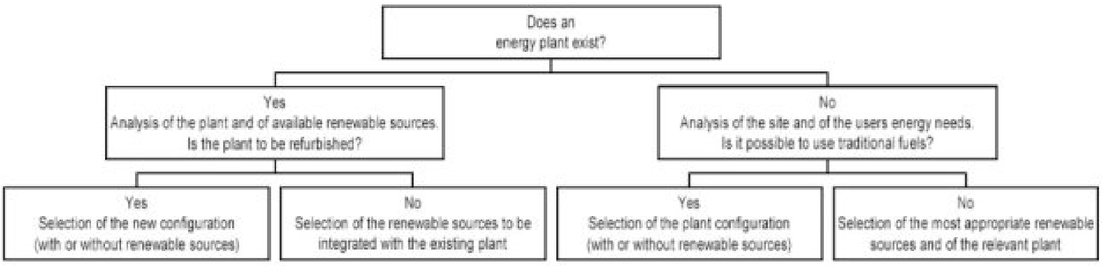

Figure 1. Basic criteria for selecting autonomous power plants.

2.2 Existing Plants: Criteria for Action

Existing plants are frequently the basis for operation. This is the case when productive activities have been operating for some time, and all of their technical aspects have been resolved (perhaps temporarily or improperly). In this context, the various energy plants have to be re-examined for any one of the following reasons:

- the energy sources employed are no longer compatible with certain environmental aspects (e.g., the use of wood in areas subject to deforestation);
- the cost of produced power is too high;
- the negative influence of the plants on actual processing or the quantity of product obtained (e.g., an electric mill which is too small to guarantee a consistent level of production).

Experience has shown that:

- In the first case, the energy source has to be replaced by one that is more suitable; in the majority of cases, this requires the choice of a new energy plant.
- In the second case, the economic incidence of the energy may be related to the high cost of the source (e.g., small quantities of diesel fuel that have to be transported for long distances) or the excessive employment of labour. Cost reductions may be obtained: by changing the energy source (again requiring a new plant); by increasing the yield (or level of automation) of the existing plant.
- In the third case, solution of the problem may require the repair of a plant malfunction or, once again, a new plant.

In all three cases, before formulating a work hypothesis, it is good practice to determine:

- the consumption levels of the technologies currently in use for the supply of electricity, broken down by energy source (e.g., grid, diesel fuel for the generation set, etc.);
- the real requirements, which are generally lower than consumption.

The next step is to determine whether consumption levels and requirements are compatible (or acceptable) in terms of:

- current energy costs;
- conversion yields (if they are too low, it is always worthwhile to consider alternative plants, at least from an economic standpoint);
- environmental impact (generally based on emissions and/or wastes of some types of energy transformations).

The proposed method of analysis can lead to two results:

- The existing plant (which may already employ renewable sources) merely requires limited modifications that do not alter its basic set-up. In this case, it is always a good idea to evaluate the benefits that could be provided by rationalizing the users (e.g., by modifying the time-table of daily operations), to obtain: a reduction in the number of user points, improved employment of labor, etc.
- The existing plant requires radical alteration. In this case, the situation is similar to the one described below.

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Biographical Sketch

Giovanni Riva was born in 1952 in Varese (Italy). University (Polytechnic of Milano): 1971–1976; Ph.D. on Agricultural Machinery in 1977; Associate Professor of Energy Technologies from 1987 at the University of Milano. Present position: Full Professor of Mechanics (relevant field: energy) at the University of Ancona (Italy). Secretary-General of the Italian Thermotechnical Committee and of the Italian Thermotechnical Association; President of the IV Section of the Italian Association of Agricultural Engineering (Energy and Rural Electrification); Member of the International Energy Economist Association (IEEA) and of the American Society of Agricultural Engineers (ASAE). Collaboration with several profit and non-profit organizations. *Tasks carried out*: design of different energy systems for rural environment; design and manufacture of dryers operating with simplified water solar collectors and PV collectors; design and preparation of tractors and generator-sets operating with raw vegetable oil. Collaboration with UN (FAO) on rural energy. Summary of goals: development and application of two models for the simulation of energy producing systems; identification of barriers to the spreading of innovative energy technologies; procedures to check the performance of innovative plants. Collaboration, as expert, with the EU in the framework of different projects on the dissemination of renewable energies (China and India). *Tasks carried out*: delivery of two tractors and one generator set working with raw and esterified vegetable oils; assistance to local institutions for the control of engine exhausts; visit to local mechanical industries for power production. The main fields of research are related to: mechanics; efficient use of conventional and renewable sources of energy. Specific topics are: data collection in different environments (also design and manufacture of instruments – data logger included – and probes); study, design and set-up of cogeneration plants up to 12 MW.