European Journal of Sustainable Development (2016), **5**, 1, 19-30 ISSN: 2239-5938
Doi: 10.14207/ejsd.2016.v5n1p19

Energy Sovereignty in Rural Areas: Off-Grid Paradigm for Strengthening the Use of Renewable Energy.

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Abstract
The policy guidelines for the UN General Assembly recognize the need of one universal and transformative agenda for sustainable development, based on the rights, and with people and the planet at the centre. This paper concerns a study of compact system designed to ensure energy independence and then energy sovereignty in marginal rural areas: the Off-Grid Box. This system is an integrated technical device, held in a 6 feet container, which provides - in a Plug&Play way – essential services and resources, namely electricity, hot water, rain water harvesting and storage for washing or irrigation and a water purification process to pasteurize or distil pure water (H_2O). Key objectives are reducing greenhouse gas emissions, increasing the exploitation of renewable energy sources, safeguarding the quality and the availability of clean water, promoting a more sustainable and healthy way of life. OGB can be modulated in different geographical contexts and demonstrate the feasibility and the strategic use of total off grid systems for individual units ensuring energy sovereignty of local communities. These systems should be designed in terms incorporated in the territory in order to realize the small-scale-smart-grid. These scenarios are interesting in rural areas especially for small family farms that adopt sustainable models and methods of production with low environmental impact and low energy demand.

Keywords: Energy sovereignty, renewable energy, off-grid system, small scale farming, rural development.

1. Introduction

The policy guidelines for the UN General Assembly recognize the need of one universal and transformative agenda for sustainable development, based on the rights, and with people and the planet at the centre (UN General Assembly, 2015). This work focuses on two of the 17 new millennium goals:

- Goal 6. Ensure availability and sustainable management of water and sanitation for all;
- Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.

Energy planning and rationalizing the use of energy are strategic issues in this historical moment. The European Union has set itself the goal of achieving by 2020 the coverage of 20% of energy needs from renewable sources and, compared to 1990, a 20% reduction in emissions of greenhouse gases and increasing by20% energy efficiency, (European Commission, 2010). At a European level the debate is open and political activity is ongoing (European Commission, 2014a).

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Fig. 1 *Six essential elements for developing the sustainable development goals (Source: Resolution of UN General Assembly, 2015)*

In the European strategy 2014-2020, rural areas are involved in specific integrated projects aimed atthe development and enhancement of local communities (European Commission, 2014b,c). Rural areas are considered strategically relevant to foster a more sustainable and inclusive national growth.

Compared to urban zones, generally rural areas are characterized by low power consumption and they are struggling to be satisfied.In these contexts it is particularly important the concept of energy sovereignty: the right of people to have access to energy and to make their own decisions over sustainable energy sources and sustainable consumption patterns. The concept of energy sovereignty is a part of the interesting alternative vision of the green economy, and is based on development models, accepted by local communities, focused on the sustainable and common use of natural resources (UN-NGLS, 2013; La Via Campesina, 2013). This concept recognises energy as a human right. It also seeks to return the control of energy users, rather than remote corporations that seek to make a profit from regardless of its impact on consumers or how it is generated (World Development Movement, 2014; Menges, 2003).

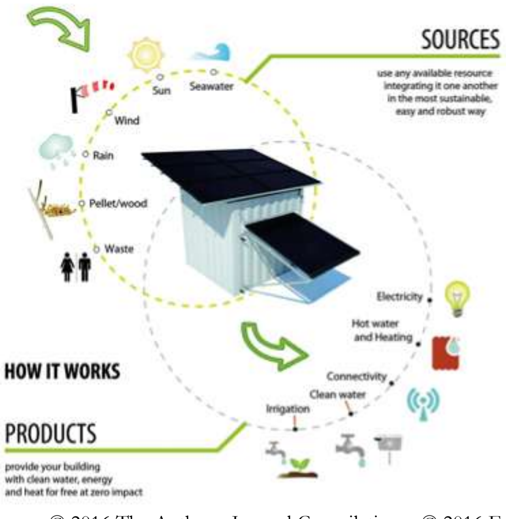
Furthermoreis very crucial the discussion around water access. Water and energy are closely interconnected and have both crucial impacts on poverty alleviation (World Water Development, 2014). Guaranteeing free access to energy and water means recognizing the sovereignty of local communities in the framework of off-grid development.

2. Research Focus

The present research analysed a case study wich is able to satisfy the energy and water needs of a residential house located in a rural and marginal area with a small kitchen garden. The technologies mix that has been studied is included in a Off-Grid Box.

2.1 The Off-Grid Box

The Off Grid Box – OGB, (designed and developed by La Fabbrica del Sole - FdS - www.lafabbricadelsole.it, an Italian group of several organizations) represented in Fig. 2, is an integrated technical device, self-contained in a 6 feet container, which provides and produces – with a simple Plug&Play concept – essential services and resources namely, electricity, hot water, clean water for washing and/or irrigation and water purification process harvesting and storage for washing or irrigation and a water purification process that pasteurize/distils waste water. The unit (OGB) has an inclined photovoltaic (PV) panelon its roof that produces electricity and harvests rain water by means of an eave with a coarse filter. This way can also be used to introduce clean water from any other source inside the OGB. Water is stored in a 1500 liters tank housed inside the unit. The captured rain water, after passing through a very fine filter process, is automatically filtered and depurated using a UV-Lamp. The same captured rain water will in addition, refill the inner liquid inside the solar water heater. The solar water heater is an indoor stainless steel tank which contains around 200 litres of liquid (simplewater or anti-freezing water or salt or contaminated water, etc...) heated by 20 vacuum glass tubes placed outside the unit facing the South side and also powered by an electric backup. On the same side, the outlet connection for the heat exchanger is installed whichcan instantaneously warm up water that flows through it and through the outlet of the clean water. The photovoltaic roof is composed of six, or more, 250 Wp mono-crystalline solar modules connected in parallel to a control panel with fuse protection (and spares) for safety standards. The panels are connected to a charge controller to charge the batteries whilst preventing the batteries from deep discharge or other potential damages. A solar inverter is connected to the batteries providing a standard (AC 110V or 220V at 60-50Hz) alternate current which can be taken from a plug affixed next to it and which is directly wired to the building, ready to plug any device on a multi-outlet at the other end of the wire. Below the batteries, additional storage space is also available for extra components which may be requested to be installed, such as large pumps, a hydrogen electrolyser, UV water filter, wind turbine accessories, and more.



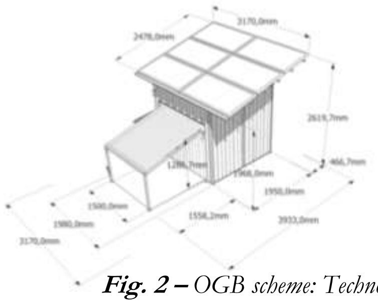


Fig. 2 – *OGB scheme: Technologies mix and dimension after complete installation.*

In view of the above, the Off Grid Box™ can be provide you with: a) the required electricity from the photovoltaic system; b) clean water from rain collection or other local sources (well, creek, etc..) and water pasteurization and distillation of contaminated and/or dirty water; c) the necessary hot water from the solar water heater; d) the possibility of adding extras such as hydrogen electrolyser, storage and burner for cooking, wood/pellet stove, high powered pressure pumps, additional water filters such as reverse osmosis for desalinization, a small scale wind turbine, and more.

1.1 Case Study: rural house in Tuscany.

One of the first installations of an OGB concerned a residential unit located in central Italy (Tuscany Region - Municipality of Pieve San Giovanni, Arezzo Province). The OGB was installed partly underground in May 2012, and the PV panels were sited on and integrated in the building's roof (Fig.3). This paper only considers the solar and the water components of the OGB system. The installed PV system covers a surface of 19,502 m2 156 and delivers 2,88 kW of power. It consists of 12 polycrystalline panels arranged in series, featuring 230 W nominal power, with dimensions 992 x1640 mm. The total roof surface is of a 210 m^2 with six different pitched roof.

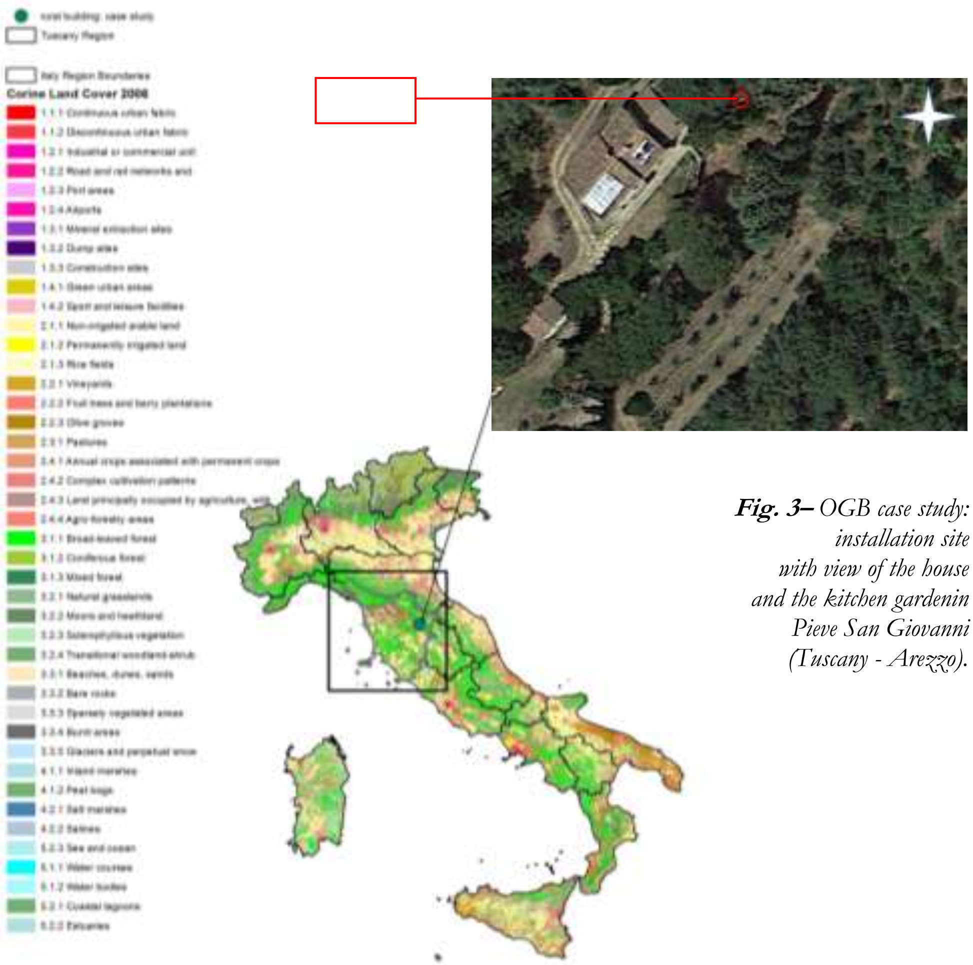


Fig. 3– *OGB case study: installation site with view of the house and the kitchen gardenin Pieve San Giovanni (Tuscany - Arezzo).*

By observing this case study it was possible to monitor, throughout 2013, the hourly energy consumption of the building and the hourly energy production of the PV system. Specifically, the amount of self-consumed energy was monitored (energy produced and consumed directly on site) both that fed into the grid and taken from the grid through net metering. As well as that it was possible to monitor, throughout 2014, the monthly rainfall level and the average consumption from a two personfamily.

The goals of the paper are (i) demonstrate the water autonomy for the small rural family (ii) investigate to assess the best storage system to be combined with a PV system in order to fulfil the energy requirements of residential buildings.

2. Materials and Methods

Fig. 4 shows the methodology flowchart.

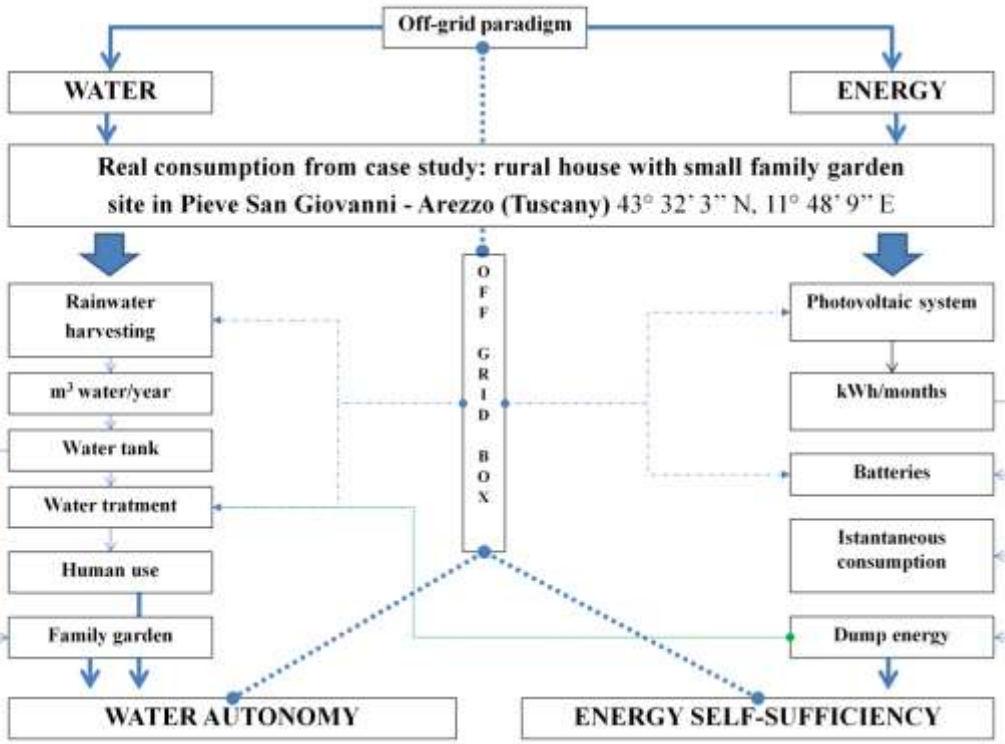


Fig. 4 *– Methodology flowchart adopted.*

For the water autonomy goal on the basis of the dataset from the Regional Hydrological Service (www.sir.toscana.it) it was possible to define the trend of rainfall for the year 2014. It was elected this time on the basis of the integrity of the data available and their reliability, the Fig. 5 shows the cumulative and daily annual rainfall.

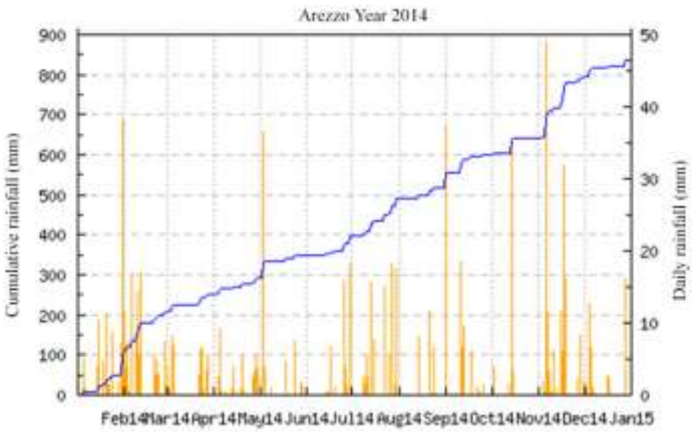


Fig. 5 *– Rainfall in Arezzo Province year 2014 (Source www.sir.toscana.it).*

The water is stored in a 6 tanks system by 1500 litres, the water surplus is distributed with overflow system. After the last tank the water go directly to the kitchen garden. OGB, with his technologies, is able to obtain different level of water purification: coarse filter, 60 micron (washable), ultraviolet sterilizer, 10 micron activated charcoal (replaceable). More over with dump energy from PV system is possible the pasteurization (>65°C treatment) and distillation (>100°C treatment).

The water consumption for human use (2 person) is calculated with reference to average national consumptions (Istat, 2013) and are illustrated in Tab.1.

Tab.1 – Average consumption for the case study (Source Istat, 2013).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Consumption for human use (litres)	10850	9800	10850	10500	10850	10500	10850	10850	10500	10850	10500	10850	127750

For the goal of energy self-sufficiency the methodology that has been followed has provided several logical steps based on the real case mentioned above: ON-GRID PV system and energy exchange with the grid(case 1). An alternative energy storage system as a first step was envisaged: PV system and OGB with Lead-Acid Battery (case2) (Salkind et al., 2014). The second step was varying the positioning of the PV system (azimuth and tilt), and surface area, thus its peak power.The logic is not to maximize the energy produced by the PV system (case 1), but to reduce the time shift, that is, the balance in time between production and use of energy.For the alternative energy storage system the use of Lead-Acid Battery is assumed, which represents mature and accessible technologies.Throughout 2013 the real case study (case 1) allowed the monitoring of energy consumption of the building and the energy produced by the PV system. For the simulation of the energy produced by the PV system for case 2, it used the open source tool "Simulare_11" available at link http://www.intellienergia.com/. Simulare is a techno-economic simulator for the design of solar photovoltaic systems designed by the

Italian Spin-off Intellienergia. With "Simulare" the optimal positioning of the panels (combinations of azimuth and tilt) was identified, setting the objective function to minimize the gap between the trends in production and consumption. The optimal orientation resultant for case 2 is characterized by an azimuth of 0 ° and tilt of 90 °, which corresponds to the positioning of panels on a vertical surface (wall of the building facing south). The dimensioning of the batteries for the simulated (case 2) is based on results from the monitoring of the real case (case 1). The solar radiation adopted by Simulare_11 comes from PV GIS data set as illustrated in Fig. 6.

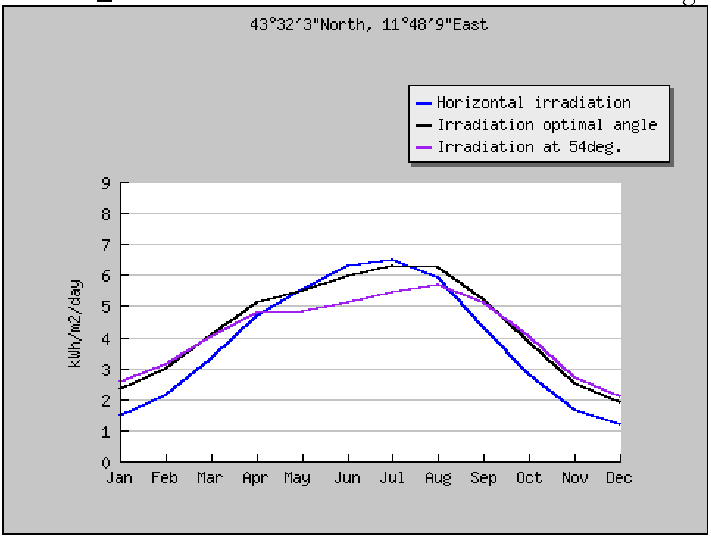


Fig. 6 *– Solar Radiation for Pieve San Giovanni year 2013 (Source http://re.jrc.ec.europa.eu/pvgis/)*

3. Results

3.1 Water Autonomy

Comparing the total consumption bythe family to the cumulative rainfall it's possible to highlight a balance in terms of litres stored and consumed on an annual scale. At the same time there isan evident problem to move the water surplus from the winter months (November, January and February) to early spring and late summer (March, April and August) (Tab. 2 and Fig. 7).

Tab.2 – Total consumption vs cumulative rainfall.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Cumulative rainfall	20109	23348	9592	8414	12242	10054	19562	5637	16995	9129	31845	9213	176139
Consumption	10850	9800	10850	10500	10850	10500	10850	10850	10500	10850	10500	10850	127750

Surplus/deficit	9259	13548	-1258	-2086	1392	-446	8712	-5213	6495	-1721	21345	-1637	48389

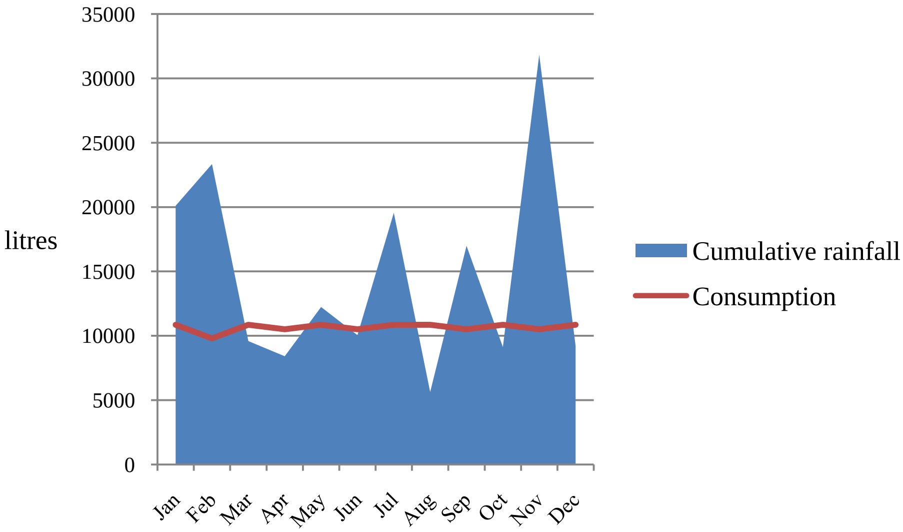


Fig. 7 *– Water balance between rainfall and consumption.*

The results of the monitoring on OGB technologies demonstrate the following performance with reference to the purification system: filter (1000 litres/h); ultraviolet sterilizer (up to 16 litres/min); with dump energy from the PV system used for pasteurized water (150-300 litres/day) and distilled water (30 litres/day). The excess of water stored and not used for human use is suitable for irrigation of the kitchen garden.

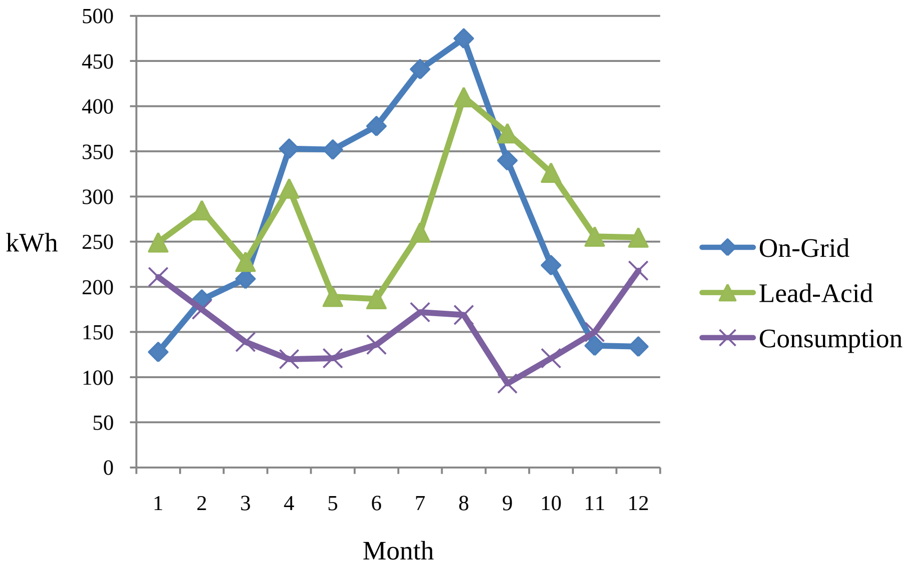
3.2 Energy Self-Sufficiency

With the tool "Simulare_11" asimulationof the monthly production for PV systems of case 2 compared with case 1 was carried out. The results are summarized in Table 3 and represented in Fig. 8.

Tab. 3 – Consumption, level of production and energy in kWh for case 1 and 2 on a monthly basis.

	Months	1	2	3	4	5	6	7	8	9	10	11	12	Total
	Consumption (instantaneous plus from the grid)	211,00	175,00	139,00	120,00	121,00	136,00	172,00	169,00	93,00	121,00	150,00	218,00	1825,00
Case 1	Production	128,00	186,00	209,00	353,00	352,00	378,00	441,00	475,00	340,00	224,00	135,00	134,00	3355,00

	Energy surplus/deficit	-83,00	11,00	70,00	233,00	231,00	242,00	269,00	306,00	247,00	103,00	-15,00	-84,00	1712,00
Case 2	Production	249,44	285,00	227,96	309,05	189,18	186,67	260,42	410,29	370,23	326,61	255,87	254,81	3325,53
	Energy surplus/deficit	38,44	110,00	88,96	189,05	68,18	50,67	88,42	241,29	277,23	205,61	105,87	36,81	1500,53



To better evaluate the efficiency of Lead-Acid batteries (case2) and for their sizing, the analysis of production levels has been accompanied with a study of certain technical characteristics of the storage system (Linden and Reddy, 2002; Battery University BU-201, 2015; The Electropaedia Battery performance characteristics, 2015).

4. Discussion and conclusion

The OGB is able to guarantee water autonomy and self-sufficient energy improving the off-grid approach in rural areas.

Regarding the water autonomy for the rural house it is possible to adopt the technologies inside the OGB useful to harvest all the potential rainfall in the specific site. The articulated renewable distillation system is able to purify water at different levels of contamination, with different processes. The average rainfall in central Italy can ensure the water consumption of a small family consistings of two people with a small kitchen garden. In this sense it is necessary to design a system of storage tanks able to ensure the water supply over time.

To achieve a real self-sufficient energy system also with OGB it is necessary to design the system for optimizing time shift and not to maximize the energy production.

The storage system evaluated and compared in this work does not permit the stored energy to be used from one month to another.For this reasonit was necessary to oversize the PV system compared to the demand in order to have higher monthly production than consumption. To make the logic of energy self-sufficiency more interesting. It is required to:

- adopt solutions as the case 2 and identify systems able to use the excess energy(see the water treatment system present in the OGB summarized in Fig. 3);
- integratethe PV system with other renewable energy sources, characterized by complementary production deployments (eg hydroelectric energy, wind power);

The OGB should be designed in terms incorporated in the territory, to obtain the small-scale-smart-grid. With these assumptions in marginal rural areas, the small scale family farms become actors of particular interest, with their restricted energy and water demand and the adoption of sustainable methods of production.

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