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HOUSING/ENERGY SOLUTIONS

FOR RURAL TOWNS IN DEVELOPING COUNTRIES

A model house designed for rural and residential areas in small towns in Guatemala is described. The model shows that low cost houses can include features of aesthetic value coupled with provisions for renewable energy, water conservation and waste control that authentically improve the quality of life in developing communities. The modular, versatile house includes sound and pleasant building, biogas plant, solar water heater, optional electricity generation, air cooling/heating, water storage/purification, waste recycling. Construction cost is competitive with non-commercial housing proposed by several governmental and non-governmental organizations. The running cost is also greatly reduced by the renewable energy and ecological features.

Among recurrent problems in small municipalities and rural areas in developing countries, particularly Guatemala, is the lack of adequate housing, the need of economical and renewable energy, the disposal of waste. Several NGOs, Foundations and Governmental Agencies, particularly Habitat [1] and Foguavi [2], have been involved in the development of affordable houses for the poorest rural component of the population. Typical houses are illustrated in Fig. 1. The basic block and lamina structure, and the involvement of the beneficiary in the construction, have allowed a drastic cost reduction. However, the spartan nature of the houses does not allow for desirable features having practical and aesthetic value, and not always translates into a substantial upgrading of the quality of life. The housing quality in urban areas of small towns in Guatemala is also extremely poor.

The Jepa-Limmat Foundation has designed a model house aiming to provide low cost but decorous living in rural as well as in urban areas, lessening the dependence upon energy providers, reducing pollution and enhancing waste control. The design and the functional characteristics of the Jepa house are described below.

House design and cost

The basic, modular design of a 50 m^2 model house is illustrated in Fig. 2. The following features of the design should be emphasized.

The exterior and the interior walls have adobe and are painted with light colors. The roof includes a terrace for the installation of a water tank, a solar water heater, two openings that assist air circulation, and an (optional) photovoltaic 300 watts system. The antiseismic structure includes cement blocks, foundations, columns reinforced with 1.5 cm diameter iron rods.

The interior of the house, suitable for a family of four, includes two rooms, a kitchen, and a bathroom with tub, shower, and storage

Fig. 1 - Typical Habitat house in Guatemala. From [1]

space. The plan allows for one or two additional rooms either on the ground or an upper floor. The communication between the various rooms is simple and functional. The floor is a treated 10 cm cement platform.
The corridor, typical of colonial design, includes three wide windows, the main door, and an undulated metal or plastic roof supported by wooden columns. Two elevated small windows (colonial-style) provide additional lighting and ventilation. A biogas plant and a pila (washing basin) are placed in the corridor.
The cost currently estimated (USD 6,000 or Q 45,000) should be easily affordable and, considering the features included in the Jepa house, competitive with the price of a 50 m^2 Habitat house (USD 4,000, or Q 30,000). The difference is mitigated by the lower running expenses for the Jepa house (cf. seq.). The cost of both houses is well below the current average price of low cost commercial housing in Guatemala (~USD 200/m^2).
The cost of the houses will be shared by the Foundation, the Municipalities, and a beneficiary owner of the land willing to assume a mortgage and committed not to sell the house for at least 10 years. Houses to be later constructed following the Jepa model might benefit from decreasing contributions by Municipality and Foundation, and will therefore require increased participation of the beneficiary.
Two houses are currently in execution in the Sacatepéquez region at San Juan Alotenango (~20,000 hab) and San Antonio Agua Caliente (~10,000 hab). Both municipalities include rural as well as urban settlements characterized by different extent of infrastructures[3]. Facilities such as municipal water, sewer system, electricity may be available only in urban areas. Accordingly, the design of the Jepa house includes versatile features suitable to a variety of infrastructural facilities.

Heating, cooling, cooking, water facilities

Standard features of the model house include: a solar water heater, air circulation, an efficient Onil stove, a biogas plant, water reservoirs and purifier.
The solar heater is a commercially available unit with vacuum tubes and a 100 l tank installed on the terrace [4]. It allows for occasional electrical heating. A more robust metal-plate solar heater, suitable in a volcanic area, is currently being designed [4]. Proper inclination and exposure to the sun should allow water temperatures up to 75 °C and re-heating times in the order of 30min. When hot water is not directly used, it can be circulated through a radiator inside the house to assist ambient heating.
Air circulation, favoring cooling or heating, is assisted by the openings on the terrace equipped with either a transparent glass or a glass-mosquito screen solution, and by the two colonial-style windows.
The Onil stove, Fig. 3, (Helps International) [5] is an efficient wood burning unit which drastically reduces wood consumption, air pollution, smoke and fires and can therefore be used inside the house.
The biogas plant and its operation have been extensively described [6] (Fig. 4). The previous model has been modified for application to the model house. We are currently using a smaller lower digester (450 l) and a heavier metal dome (assuring smooth gas delivery) than previously described. Moreover, the plant is situated outside the house, under the roof of the corridor, and can be fed directly from the kitchen. As already indicated, it uses the vegetable waste produced by the family to generate sufficient gas (~100 l) for their daily cooking [6].
The water reservoir is a commercially available 450 l tank equipped with antibacterial membrane. It receives water from the municipal network (urban areas) or from a well (rural areas). Additional water storage is provided by the pila (~300 l) that receives rain water from the terrace.
The water purification unit (Helps International) [5] is a 62x45 cm deposit stored in the kitchen, equipped with a ceramic filter and activated carbon.

Electricity generation

A small solar photovoltaic system has been designed for installation on the terrace of the Jepa model house [7]. The plant includes four solar panels (Isofoten I-75, having a nominal 75 watts power) spread over an area of ~4 m^2, two 6 volt batteries (Trojan L-16, 375 A-H), charge regulator, inverter (Morningstar Suresine 12 volt, 300 watts) and five long-life bulbs (12 volt, 10,000 hours). The scheme of the installation, illustrated in Fig. 5, includes the possibility of transferring to the grid any excess energy. Due to the high cost of the system (~4,000 USD), it will be installed only in one model house to introduce the technology to the community. Regulations allowing

Fig. 2 - Model JEPA house

Fig. 3 - Onil stove. From [4]

Fig. 4 - New biogas plant

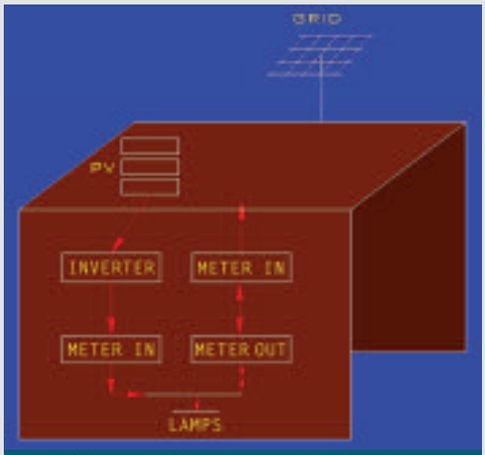

Fig. 5 - Scheme of a PV system coupled to the grid

the sale of unused energy, as well as Governmental incentives have yet to be adopted in Guatemala.

An alternative possibility for electricity production, of interest in rural areas, is based on the use of biogas to aliment a conventional generator. A four-stroke gasoline generator, with an electrical energy output in the order of 500 watts, can be suitably coupled to the biogas plant [8]. The biogas flow to the carburetor of the generator is complemented by a device allowing mixing with air. An output in the order of 100 watts/hour, adequate to supply of the long-life bulbs used in the model house, is expected from the 100 l biogas daily produced.

Ecological and safety features

The Jepa house permits an efficient approach to waste reduction and control. As previously indicated [6], the use of biogas introduces the community to the need and the habit of separating the vegetable organic material from plastic, glass, metal and other non-digestible materials. The digested effluent is an excellent fertilizer particularly needed in rural areas. In the latter areas, a connection between the toilet and the biodigestor, or the addition of animal excreta, may be considered in order to enhance the production of biogas and fertilizer, with simultaneous degradation of pathogenic bacteria [6, 9]. The separation of discarded components facilitates the recycling process, and the production of fertilizer or energy at the landfill site.

The combination of biogas and Onil stoves allows a significant reduction on the use and cost of conventional combustibles such as liquefied gas or wood, correspondingly reducing atmospheric pollution [6]. Consumption of electricity is also greatly reduced in the Jepa house due to the solar heater and the air circulation system.

No combustible gases or odors are stored or produced in the house. The biogas, produced and stored outside, is piped directly to the burner inside the kitchen. The new plant allows for a cleaner, automated operation and is tailored to the actual need of the family.

Continuous water supply is assured by the two reservoirs (tank and pila). The ceramic filter of the purifier remove particles larger than 0.5 mμ (e.g., disease causing bacteria), while the activated carbon reduces the level of chemical components, improving the taste of water [5].

Conclusions

Due to the coupling of sound building with aesthetic characteristics, ecological features, low cost of the structure and running expenses, the Jepa model house is intended to offer an authentic upgrade of the quality of life of its occupants. The versatile model is suitable for application to rural areas of small towns in Guatemala, as well as other fast developing Countries. The model should be of great interest also for upgrading urban areas usually hosting shanty, decaying houses.

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References

[1] www.habitat.org/intl/lac/86aspx
[2] www.congreso.gob.gt
[3] C.L. Choguill. Ten Steps to Sustainable Infrastructure, Habitat International 20, 389-404, 1996.
[4] www.sunstar-solar.com, www.sitiosolar.com, www.aidg.org
[5] www.helpsinternational.org
[6] C. Cojolon, L. Estrada, E. Toledo, A. Ciferri, *Chimica e Industria*, 2008, **90**(2), 130, www.jepafoundation.org
[7] J. Diaz. Installation of a PV System in Alotenango, Thesis, Department of Chemical Engineering, University of Cadiz. Spain 2008.
[8] N. Mejia. Electricity Generation from Small Biogas Plants. Work in progress, Faculty of Engineering, University of San Carlos of Guatemala, Guatemala 2008.
[9] O.P. Chawla. Advances in Biogas Technology. Indian Council of Agricultural Research, New Delhi, 1985, p. 80-82.

ABSTRACT

Soluzioni per l'energia domestica di aree rurali in Paesi in via di sviluppo

Una casa modello, disegnata e costruita in Guatemala, coniuga caratteristiche di economicità, di estetica e di energia rinnovabile che consentono un autentico miglioramento della qualità di vita in aree urbane e rurali di Paesi in via di sviluppo. Il costo è competitivo con quello di case proposte da organizzazioni governative e non-governative senza fini di lucro, che mirano principalmente ad una riduzione dei costi di costruzione. Problemi d'inquinamento ambientale e costi di gestione della casa modello Jepa sono mitigati dall'uso di biogas, energia solare, riciclo dei rifiuti, conservazione e purificazione dell'acqua.