International Conference on Renewable Energies and Power Quality (ICREPQ'15)
La Coruña (Spain), 25th to 27th March, 2015
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, No.13, April 2015

Technical and economic feasibility of the use of Solar Thermal Energy in Condominiums with Popular Dwellings

Moraes-Santos, E.C.[1], Souza, T. M.[2] and Balestieri, J.A.P.[3]

[1,2,3] Department of Energy
UNESP Campus of Guaratinguetá (www.feg.unesp.br/energiasrenovaveis)
Av. Ariberto Pereira da Cunha, 333. Guaratinguetá, SP, Brazil –
Phone: 55-12 31232800, e-mail: **pos13007@feg.unesp.com,br**[1] , **teófilo@feg.unesp.br**[2] , **perrella@feg.unesp.br**[3]

Abstract. The proposed works consists in the research on the electric power consumption in a Brazilian municipality and effective financial economy and demand the power grid with the installation of solar water heating. The field research was conducted with the survey method with questionnaires applied in a sample of 360 households. As a result it was confirmed that 55,28 % of interviewed households has electric power consumption between 151-200 kWh; all of them have electric shower with an average use time 1 hour/day, the use between 18:00 and 21:00 pm, peak time in Brazil. Therefore, the use of solar thermal energy represents a savings of 12,000 kW / ano for the city and reduce demand electricity grid. Research has proven that low-cost solar water heater is viable to be installed.

Key words
Solar water heating, popular dwellings, electric power consumption, energy efficiency.

1. Introduction

The energy, as well as its form of production and consumption is essential for all social, environmental and economic organization. Environmental and social impacts arising as a consequence, considering that there is no economic development without the use and supply of energy. For the effects of environmental and social impacts of production and use of energy are mitigated, a possible alternative is to resort to the use of renewable energy. In this context, Brazil and especially in the regions with the highest indices of insolation, the use of solar energy can be widely used.

Among the various processes of solar energy, the most currently used are water heating and photovoltaic power generation. In Brazil, the first one is more found in South and Southeast regions due to the climatic conditions, and the second, in the North and Northeast regions, in isolated communities of the power grid, [1].

The Brazilian market is growing in the use of solar energy and sectors of the Brazilian government are encouraging its use through social programs. The main argument is the economic and environmental benefits of equipment such as electric showers, which represents 20-30% of electric power consumption.

Energy planning grounded in technical studies, with methods that use a combination of probable and possible interfering variables in the path of the various social, economic, financial, environmental and energy structures, among others, can be defined that allows the best intervention, with less cost, less environmental damage, better energy strategy and greater social benefits. These instruments assist policy decisions to define development models that society indicated which are implemented by rulers chosen, [2].

Due to the lack of information on case studies which evaluate technical and economic viability of the insertion of solar water heating in households of Brazil's municipalities, this work contributes to research and encouragement in this exposed area. Evaluates the knowledge and acceptance of the insertion of the solar water heater system with a case study in the municipality of Tremembé, in the state of São Paulo, Brazil, by social class. And also analyze the profile of electric power consumption of the inhabitants and the financial economy through insertion of the solar technology.

2. Materials and Methodology

The methodology used in this study is divided into two stages: the first stage it is through the sampling plan used to evaluate the knowledge and acceptance of the insertion of solar water heaters in the households. The second step consists of analyze the profile of the electric power consumption of sample households and the economy in the cost of electric power in the installation of solar water heater.

The registers of the census sectors of the Brazilian Institute of Statistics - IBGE 2010 [3], were utilized. Were used format maps kmz (Fig. 1), maps of descriptions of 85 sectors that totalling the municipality Tremembé for the location and georeferencing of each sample household.

The sampling plan must have a maximum error of 5% within a confidence interval of 95% and it was a sample of 371 in a population of 10,632 households. Therefore is within the desired estimate.

The equation (1) was used for the sample calculation.

$$n = \frac{z^2.[\left(\frac{x}{n}\right).\left[1-\left(\frac{x}{n}\right)\right].N}{(N-1).e^2 + z^2.\left(\frac{x}{n}\right).[1-\frac{x}{n}]} \qquad (1)$$

Where:
n = size of the sample
N = size of the population
e = % error in unitary form
Z = confidence interval
$\frac{x}{n}$ = expected ratio

The Figure 1 shows the map in kmz format where the location of the sampled households were located in each sector.

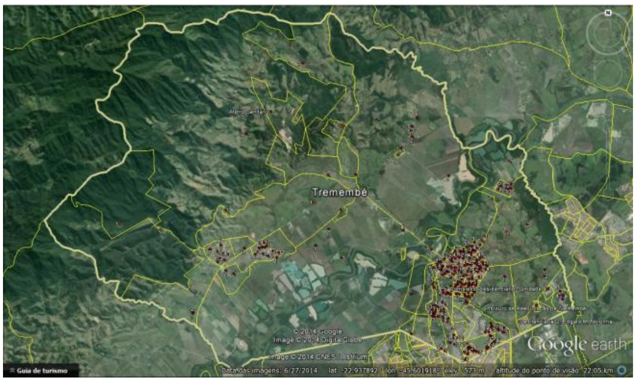

Fig. 1, map in kmz format and the localization of the households
Font: (IBGE, 2014, Author,2015)

The information collected through the survey method were inserted into worksheets in excel format and the data were treaties statistically.

The Figure 2 shows a sample of the worksheet data in excel format about the consumption of electric power in the sampled households.

	A	B	C	D	E	F	G	H	I	J
1	Cód	Setor	Nº EdP	Consumo	Incand 60W	Incand 100W	Fluo 12W	Fluo 20W	Fluo 40W	Econ.Energ
2	1	00001	39452697	mais250kWh	0	0	9	9	0	ambos
3	2	00001	0	101-150kWh	5	0	0	7	0	tira tomada
4	3	00001	39722449	mais250kWh	6	0	0	3	0	tira tomada
5	4	00001	39721221	201-250kWh	0	0	3	9	0	ambos
6	5	00002		151-200kWh	0	1	0	9	0	apaga luz
7	6	00002		101-150kWh	0	0	0	9	0	ambos
8	7	00002		101-150kWh	0	0	0	10	0	ambos
9	8	00002		151-200kWh	0	0	0	11	0	ambos
10	9	00002		151-200kWh	0	0	0	10	0	ambos
11	10	00002		101-150kWh	0	0	0	16	0	ambos
12	11	00002		151-200kWh	0	0	0	12	0	ambos
13	12	00003	76776441	201-250kWh	6	0	0	18	0	ambos
14	13	00003	0	51-100kWh	0	0	0	8	0	ambos
15	14	00003	0	101-150kWh	0	0	0	18	0	ambos
16	15	00003	42478527	201-250kWh	0	0	0	8	0	ambos
17	16	00003	42476542	151-200kWh	0	0	0	11	0	tira tomada
18	17	00003	90307003	mais250kWh	0	0	0	10	0	ambos
19	18	00004	90006186	mais250kWh	0	0	0	14	2	apaga luz
20	19	00004	40450732	mais250kWh	0	0	0	6	9	apaga luz
21	20	00004	0	201-250kWh	0	0	0	5	5	apaga luz
22	21	00004	40452352	151-200kWh	0	0	0	5	7	apaga luz
23	22	00004	0	101-150kWh	0	0	2	0	4	apaga luz
24	23	00005	42734266	mais250kWh	4	0	0	4	0	apaga luz
25	24	00005	42737133	151-200kWh	0	0	0	17	0	ambos
26	25	00005		151-200kWh	0	0	0	12	0	ambos
27	26	00005		151-200kWh	0	0	0	10	0	ambos
28	27	00005		151-200kWh	0	0	0	10	0	ambos
29	28	00006	4273117	mais250kWh	0	0	0	9	2	apaga luz
30	29	00006		151-200kWh	0	0	0	10	0	ambos
31	30	00006		151-200kWh	0	0	0	10	0	ambos
32	31	00006		151-200kWh	0	0	0	12	0	ambos
33	32	00006		151-200kWh	0	0	0	11	0	ambos
34	33	00006		101-150kWh	0	0	0	10	0	ambos
35	34	00006		101-150kWh	0	0	0	8	0	ambos
36	35	00006		101-150kWh	0	0	0	10	0	ambos
37	36	00007		151-200kWh	0	0	0	10	0	apaga luz
38	37	00007		51-100kWh	0	0	0	11	0	apaga luz
39	38	00007		101-150kWh	0	0	0	11	0	apaga luz
40	39	00007		101-150kWh	0	0	0	11	0	ambos
41	40	00007		101-150kWh	0	0	0	12	0	ambos
42	41	00008		151-200kWh	0	0	0	10	0	ambos

Fig. 2 Sample of the worksheet data about the consumption of electric power in the sampled households.
Fonte: (Author, 2015)

As for bath time, the data indicate that 90.28% of the residents use the electric shower in peak time. Which, in Brazil, is stated between 18:00 pm and 21: 00hs. As shown in Figure 3.

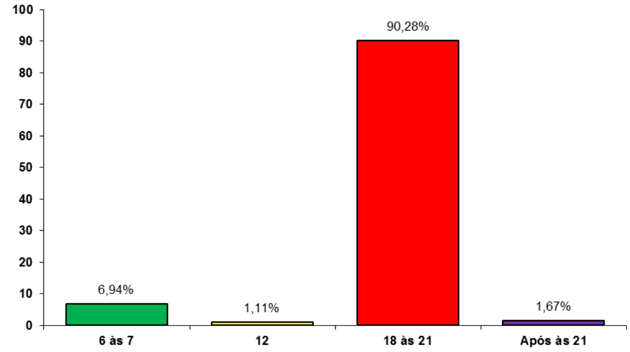

Fig. 3 - Graphic with data on bathing time of the sampled population.
Font: (Author, 2015).

As the use of lamps, research shows that fluorescents compact lamp 20W is the most used in all dwellings and residents show knowledge that such lamps have higher energy efficiency and incandescent lamps ceased to be used.
Regarding the consumption of electricity, the data confirm that 55,27 % of housing is between 151 and 200 kWh. As illustrated in Figure 4.

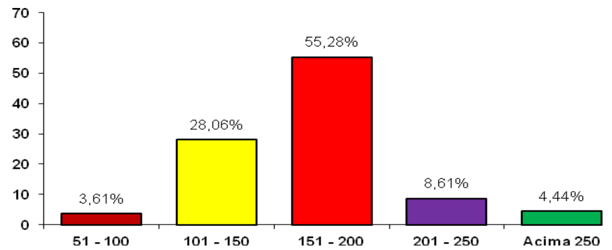

Fig. 4 - Electricity consumption per household
Fonte: (Author, 2015).

3. The solar collectors

The simplest and most economical way to harness solar energy is generating potable water for domestic use, commonly known as domestic hot water. Installation is simple and has a low cost and is amortized in a short time, [6]
The research examined three available types of heaters in the Center for Renewable Energy at UNESP, Guaratinguetá. The water heater low cost - ASBC, revealed lower cost and presenting the same energy efficiency than heater plans solar. For the installation of a water heater with PET bottles are required: a box of cold water, a boiler, PET bottles, pipes, curves and Ts PVC, two metal taps and registration.
The Figure 3 shows the ASBC, installed on Renewable Energy Center of UNESP, Guaratinguetá, SP.

The system provides hot water at varying temperatures between 40 ºC and 60 ºC, basically meeting the demands of residential use in kitchens, bathrooms and laundries.

Fig. 3, ASBC installed on Renewable Energy Center of UNESP, Guaratinguetá, SP.
Fonte: (**A**uthor, 2014)

3.1 Cost of Installation

For the installation of a Solar Water Heater Low Cost, with the use of PET bottles of 2 liters, constructed as shown in Figure 3, the financial investment is U$ 497,75 and the description and prices of materials required are described in Table 1.

Table I. Description and price of materials necessary for the construction of a solar heating system built with PET bottles.

Material Description	Amount	Unit Price	TotalPrice
Reservoir of 200 L	01	U$ 434,60	U$ 434,60
PVC pipe hot water of 12 mm	02	U$ 4,08	U$ 8,16
PVC pipe of 12 mm (6 mt)	14	U$ 1,42	U$ 19,88
Connections T of 12 mm	72	U$ 0,24	U$ 17,28
Connections curves of 12mm	07	U$ 0,17	U$ 1,19
metal tap	02	U$ 6,30	U$ 12,06
Water registry	01	U$ 4,58	U$ 4,58
		Total	**R$ 497,75**

3.2 The financial economy and electricity saving

The electricity savings is 12.000.000 kWh to the city with over 10.000 inhabitants. The cost of 1 kWh is U$ 0,11. Thus, with the use of solar heaters can save up to U$ 2.748.826,08/y, according to equation (1) and also avoid emissions of CO_2 in the atmosphere.

$$E_{economia} = 12.000.000\ .\ U\$\ 0,11 \qquad (1)$$

$$E_{economia} = U\$\ 1,320,000$$

4. Conclusion

The data presented show that 86.11% of households consumes 201-250 kWh of electric energy. Being that 90.28% of the residents making use of the electric shower, to which is responsible for almost 50% of the electricity cost, occurring during peak hours, between 18:00 pm and 20:00 pm. They know the technology of Solar Energy, but they unaware about the solar water heaters low cost - ASBC. And 100% of the respondents from the rural area, have an interest in knowing and install solar water heaters low cost.

The solar heater with PET bottles can be built by the dwellers themselves, not requiring specialized labor.

Is necessary to present guidelines for the inclusion of low-cost technologies that encourage energy saving and water and such guidelines should be included in educational systems. Is necessary to present guidelines for the inclusion of low-cost technologies that encourage energy saving and water and such guidelines should be included in education systems, environmental education, however, without creating a culture of dependency, offering an instrument of autonomy, so that the residents will be able to build their equipment and still be a multiplier actor.

Acknowledgement

Acknowledgement to CAPES for financial support and the residents of the municipality of Tremembé interviewed.

References

[1] BRASIL, Chigueru Tiba, et al. Cepel. **Solarimetric Atlas of Brazil:** banco de dados solarimétricos. Pernambuco: Ed. Universitária da Ufpe, 2000. 111 p. 2014 b. Disponível em: <http://www.cresesb.cepel.br/publicacoes/download/Atlas_Solarimetrico_do_Brasil_2000.pdf>. Acesso em: 13 abr. 2014.

[2] FANTINELLI, J. T. **Analysis of the evolution of shares in spreading solar water heating for affordable housing:** Estudo de caso em Contagem - MG. 2006. 208 f. Tese (Doutorado) - Curso de Planejamento de Sistemas Energéticos, Departamento de Engenharia Mecânica, Universidade Estadual de Campinas, Campinas, 2006.

[3] INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – **Census 2010.**

[4] KULB, José Ronaldo; PEREIRA, Luciano Torres; MESQUITA, Lúcio. **Designing Solar Heating Systems for Multifamily Dwellings.** Abrava: Dasol**,** São Paulo, 2013. Disponível em: <http://www.dasolabrava.org.br/publicacoes/aquecimento-solar/>. Acesso em: 30 maio 2014.

[5] PINTO JUNIOR, Helder Queiroz et al. **Energy Economics:** fundamentos econômicos, evolução, história e organização industrial. 3. ed. Rio de Janeiro: Elsevier Editora Ltda., 2007. 343 p.

[6] SOUZA, TEÓFILO M.; **Sistemas Renovables**, Energia Solar, 2011.

[7] ULLAH, K.R. et al. A review of solar thermal refrigeration and cooling methods. **Elsevier: Renewable and Sustainable Energy Reviews.** Malaysia, p. 499-513. 15 mar. 2013. Disponível em: <www.elsevier.com/locate/rser>. Acesso em: 29 nov. 2014.