Viability Study of Implantation of a Solar Water Heating System in the Maternity School of the Federal University of the Ceará

C. R. Schmidlin Jr., A. B. Moreira, A. H. Pereira, L. C. J. Silveira, P. C. M. Carvalho, e T. N. Cavalcante Neto.

Abstract– **The present article aims at to study the viability of implantation of a solar water heating system in the Maternity School Assis Chateaubriand – MEAC –, one of the units of the Federal University of Ceará – UFC. With this, it is objectified to promote economy of electric energy and consequently of resources, allowing the best administration of the unit. The choice for the subject must the two factors mainly: first, the characteristic of the unit consumer, in which the water heating, destined to the bath of the babies, it is made from electric taps spread by diverse points of the construction; second, the characteristics of the state of the Ceará, which presents one high solar potential (insolation greater that 2,800 hours/year), available in every month, being worthless the climatic changes caused per the stations of the year.**

Keywordse—**Water heating, solar energy.**

I. Introduction

The public sector comes crossing a period of great turbulences that demands of the organizations and the professionals a new strategical vision, acute creative capacity and critical assimilation of new concepts, paradigms and values. This new scene imposes greater rationality and managemental efficiency, containment of costs and technological innovation.

In the electric sector, in turn, still can be seen the consequences of the privatizations of the services and the rationing, respectively: the release of the prices of the tariffs of electric energy and the search for new energy alternatives.

Between these two movements, the Energy Management emerges. This one, applied to the environment of public hospitals it can come to reduce its costs with energy, assisting to them in its administration, so made it difficult for the scarcity of resources.

In this direction, the study presented here considers the substitution of the of the existing water heating system in the Maternity School Assis Chateubriand, that it has as power plant the electricity, for a solar heating system.

This proposal is signed by the UFC's (Federal University of Ceará) Electric Energy Conservation Program – PROCEN –, which is composed for professors and pupils (of master and graduation) of the proper institution and that it aims at three main goals: (a) to become electrically efficient the installations of the UFC, objectifying the economy of energy and public resources; (b) to contribute for the formation of professionals enabled in the area of energy efficiency; and (c) to awake the conscience of the conservation of energy in the faculties and learning, beyond the involved professionals in the administration and maintenance of the university.

For such, the PROCEN makes use of the most recent concepts of energy efficiency, including the alternative power plants, mainly the solar one, which presents a great potential of exploitation had to the climatic characteristics of the Brazil's Northeast region.

II. Characterization of the Unit

The Maternity School Assis Chateaubriand (Fig. 1) – MEAC –, one of the units of the Federal University of Ceará – UFC, is destined to take care of to the devoid pregnant women of the city of Fortaleza and it metropolitan region, being responsible for about 8.000 annual childbirths. He is also one of its objectives to assist in the formation of the pupils of medicine of the UFC, allowing to the students the practical observation of the disciplines of obstetricses, gynecology, pediatrics, beyond others.

Fig. 1. Façade of the Maternity School Assis Chateubriand - MEAC.

The MEAC makes use of the hot water with the purpose to provide a bath at pleasant temperatures to the just born babies.

The existing water heating system is currently composed for a total of 7 (seven) electric taps, with a power of 5.200W each one, spread for diverse points of the unit.

Had to the characteristics of the load (raised power and constant use in elapsing of the day), it is objectified to study the viability of the exchange of this electric heating system for one that makes use of the solar energy. With this, the economy in the expenses with electric energy of the maternity and consequently of public resources is aimed at, what it can come to improve the attendance to the patients.

III. Solar Energy

The interest for the alternative energy sources appears of the recognition of that the conventional forms of energy currently in use are limited and eventually exhaustible energy forms. In this context, the solar energy is seen as a highly interesting alternative, for if dealing with a clean renewable energy source, limitless and available in all the globe.

Daily the Sun transmits a great amount of energy through the electromagnetic waves. The incident energy, for unit of time, in a perpendicular area to the direction of the propagation of the light and measure in the top of the atmosphere of the Earth is called solar constant [7], being that, according to NASA/ASTM, its value is of 1.353 W/m^2 [6]. However, more recent measurements have pointed its value as being of 1.372,7 W/m^2 [4].

As described above, the solar constant is measured in the top of the terrestrial atmosphere, or either, in full space. Had to this, the radiation that reaches one point in the terrestrial surface is not equal to the solar constant, had it to suffer, in its trajectory, some influences, such as: latitude, stations of the year, hour of the day, atmospheric conditions and sky conditions.

As consequence of these factors, it is verified that, in elapsing of the period of one year, the tropical regions (where the state of the Ceará is located) receive more solar energy that tempering regions.

The knowledge of the radiation intensity and the ambient temperature are of basic importance for the good project and future performance of the installation of solar heating.

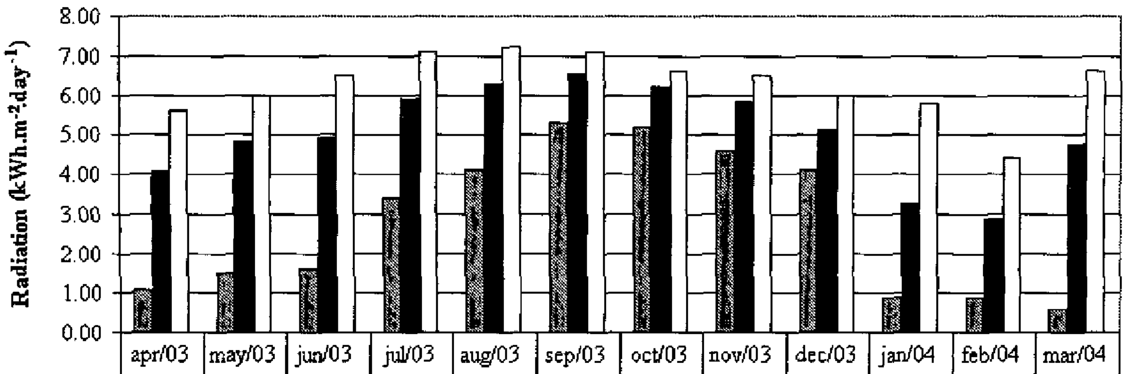
From data caught for the Energy Processing and Control Group – GPEC –, a laboratory entailed to the UFC Electric Engineering Department – DEE – and a regional reference in the research of the exploitation of the solar energy by photovoltaic way, it was arrived the graphs shown in the Fig. 2 and Fig. 3, through which it can be observed, respectively, the values of global solar radiation (kWh.m^{-2}.day^{-1}) and ambient temperature (°C) for the period of one year, since the month of April of the year of 2003 until March of the year of 2004 and in the period of the 5:00 AM at 6:00 PM.

The described values are not only characterized for its raised magnitude, compared with industrialized countries (whose that more make use of solar energy exploitation technologies), but also for its little variation during the year. This comes to confirm the potential of the state of the Ceará in the exploitation of the energy proceeding from the Sun.

IV. Solar Water Heating System

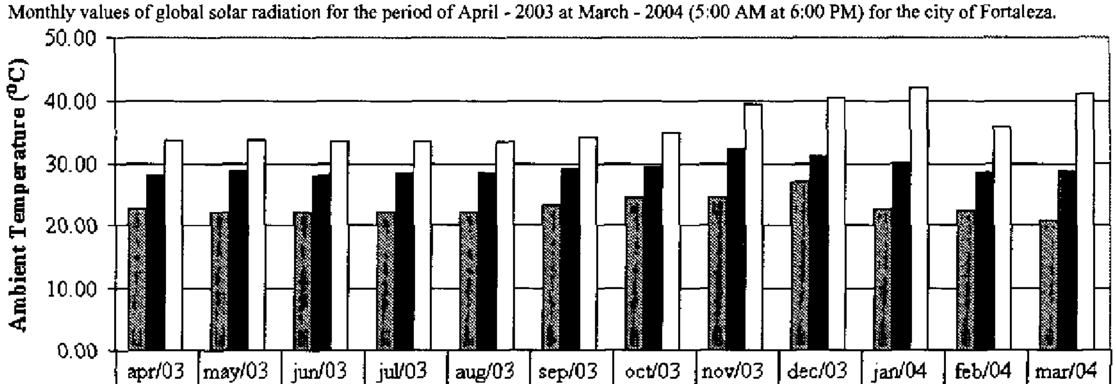
Amongst the thermal systems that have the solar energy as energy source, the water heating systems that make use of plain plate collectors are more spread out. These are ideal for the heating at temperature levels lower than 50°C and, therefore, they are wide used for water heating in residences, hospitals, hotels and other localities, providing comfort and reduction of the consumption of electric energy.

This technology already comes being used in Brazil since 60's (time where the first research had appeared) and, from 1973, the companies had started to use it commercially. It can be said that today this technology already meets total dominated, particularly by the state of Minas Gerais. An example of this is the fact that the Energy Company of Minas Gerais – CEMIG –, already possess programs with incentive of solar water heating for residential constructions [3].



	apr/03	may/03	jun/03	jul/03	aug/03	sep/03	oct/03	nov/03	dec/03	jan/04	feb/04	mar/04
Minimum	1.10	1.50	1.60	3.40	4.10	5.30	5.20	4.60	4.10	0.90	0.90	0.60
Average	4.07	4.84	4.95	5.92	6.28	6.56	6.22	5.84	5.13	3.25	2.87	4.73
Maximum	5.60	6.00	6.50	7.10	7.20	7.10	6.60	6.50	6.00	5.80	4.40	6.60

Fig. 2. Monthly values of global solar radiation for the period of April - 2003 at March - 2004 (5:00 AM at 6:00 PM) for the city of Fortaleza.



	apr/03	may/03	jun/03	jul/03	aug/03	sep/03	oct/03	nov/03	dec/03	jan/04	feb/04	mar/04
Minimum	22.63	22.26	22.20	22.25	22.29	23.30	24.51	24.61	27.19	22.72	22.39	20.90
Average	27.97	28.64	28.13	28.44	28.54	29.32	29.53	32.18	31.15	30.16	28.60	28.73
Maximum	33.75	33.70	33.35	33.48	33.50	34.16	34.84	39.41	40.52	41.97	35.67	41.07

Fig. 3. Monthly values of ambient temperature for the period of April – 2003 at March – 2004 (5:00 AM at 6:00 PM) for the city of Fortaleza.

In general, the water heating systems with solar plain plate collectors are composites for: solar collectors, reservoir of warm fluid storage, auxiliary energy source and a warm fluid distribution subsystem.

A. The Solar Collector

The solar collector is a relatively simple equipment responsible for the captation of the energy radiated for the Sun and its consequent transmission for the water. As it can be seen in the Fig. 4, the collector is composed for a absorber plate (wing in copper), canalizations (copper pipes), a transparent covering (glass), a thermal isolation and a external box.

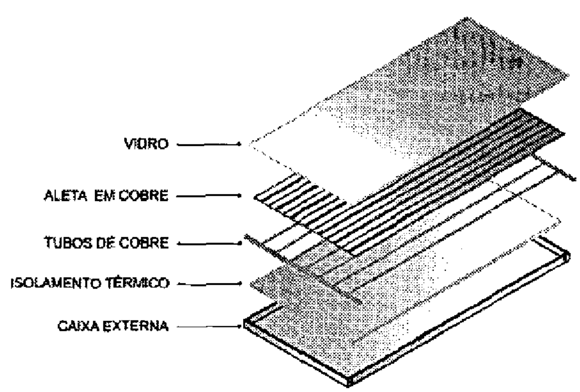


Fig. 4. Typical section of a plan collector.

In summary, the absorption of heat for the collector occurs of the following form: (a) a portion of the solar rays crosses the glass covering (the another part it is reflected and absorbed) reaching the black absorber surface; (b) this last one, in turn, will heat, leading part of the heat for the grid or coil of pipes where it circulates the water; (c) finally, part of this heat will warm the water [9].

In the installation of the collectors, some aspects must be observed to improve the exploitation of the available energy, like the geographic orientation, the angle of inclination with the horizontal line and the occurrence of shades on the structure.

B. Thermal Reservoir

Due to demand for warm fluid not to coincide, in the majority of the applications, with the period of its offer, the use of a thermal reservoir is necessary. It prevents the losses of heat, conserving the water hot until the moment of its use, either during the day or the night. Its volume is defined in agreement with the daily consumed hot water.

C. Auxiliary Power Plant

The purpose of the of solar heating system is to save electric energy or another fuel, never being projected to supply 100% of the hot water demand. In case that it were thus projected, the result would be a over-designed system for most of the use time. Thus, the solar system is projected to supply 50-70% of the total demand of heating [5].

In the sunny days the system constantly acts making the all volume of the thermal reservoir is warm. The maximum temperature reached by the water in the thermal reservoir depends on the station of the year, of the intensity of daily radiation and the sizing of the installation.

In the hidden days the solar heating system makes use of the diffuse radiation. In the summer, only this radiation can be enough for the full heating of the tank.

In the rainy days, for not having incidence of usable solar radiation in the plates, the solar heating system is inoperative. Had to this problem, becomes necessary the use of a auxiliary power plant.

D. Installation Topology

In accordance with the type of circulation of the fluid between the collectors and the thermal storage reservoir, the solar heating systems can be classified as passive or active. When the circulation of the water occurs exclusively for the density difference, the heating system is known as a passive system. When the circulation of the water is made by a pump, it is related as an active system or a pumped system.

The passive type system makes use of the property of the water of being less dense (more led), when warmed. Thus, by a natural process and without external intervention, the warmed water flows for the thermal reservoir. This installation type is indicated in any situation, therefore require no maintenance, no pumps and no external control, depending exclusively on the terrestrial gravity.

However, to be possible this type of installation, the disposal of the component elements of the installation must take care of certain requirements. Table I shows some examples of values to be reached (given for a certain manufacturer) [8] and the Fig. 5 locate them in a typical installation.

TABLE I
REQUIREMENTS FOR THE OPERATION OF A PASSIVE TYPE SYSTEM

	DISTANCE (m)	
	Min	Max
X	0.15	5
Y	0.2	4
Z	0	6

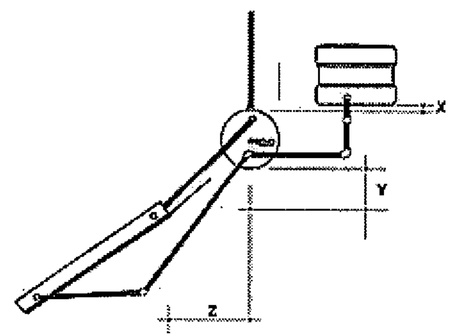


Fig. 5. Distances of a passive pumping system.

How much bigger will be the distance Z shown above, greater will be the loss of load and, therefore, greater will have to be the distance Y, that must be at the very least of 10% of Z.

If this type of installation will not be possible (due to space limitations), the use of a water pump will be necessary.

V. MEAC Solar Water Heating System Project

The project of a solar heating system must be elaborated to provide the continuous supplying of hot water at ideal amount and temperature and at the most possible economic way. Thus, the main parameters to be considered in the project of any water heating system are the daily hot water demand and the desired temperature.

The first step for the installation of this type of system is the survey of the pertinent information. The use of the hot water, the place where the solar heating system will be implanted, the consumption points, etc. This stage is extremely important, therefore it will define the performance of the system. Disrespecting some important factors in this process, the system will no able to operate as desired.

From the survey of the hot water points, it was verified that the distribution of these in the MEAC describes three vertical lines, from the roof. Each one enclosing a certain area, which is shown in Fig. 6. This type of distribution, beyond other factors, made impracticable the use of a central system, which would demand an extensive hot water distribution grid. Therefore, it was opted for the use of three independent systems.

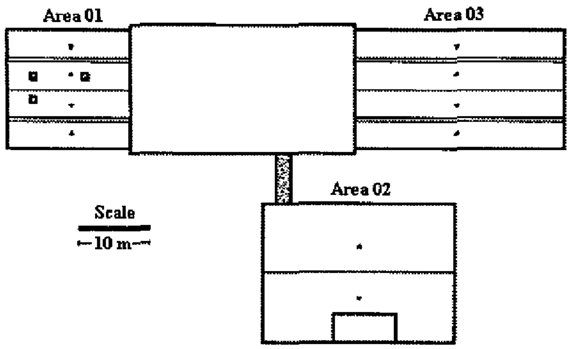


Fig. 6. Localization of the three water heating systems in MEAC.

The analysis of the physical structure of the maternity disclosed the possibility of the installation to be of the passive type, excusing the use of a pump.

For the determination of the water temperature at the final use points, had been carried through interviews with the doctors and nurses of the related maternity. They had informed that, for the bath of the babies, it was necessary hot water at temperatures between 36-37°C, that is, a low temperature rage for the taste of an adult, that turns around 45°C. Thus, was verified that a water heating system with plain plate collectors (normally used in adults bath) is enough to take care of the MEAC hot water necessities.

With the survey of the hot water points also it was possible to verify the consumption for each area during the day and to determine the amount of collecting plates and the volume of the reservoir for each one of the three systems, as it shows Table II.

VI. Economic Analisis

The economic analysis here described aims to evaluate, under the point of view of the consumer, the financial attractiveness of the instalation of the existing solar water heating system. So, it was opted to the attainment of the relation of benefits and costs (RBC), an evaluation method considered for the National Agency of Electric Energy – ANEEL – in its Manual for Elaboration of the Program of Energy Efficiency [1].

TABLE II
Basic Description of the Considered Heating Systems

Place	Reservoir		Plates
	Volume (liters)	Auxiliary Resistance (W)	Total
Area 01	300	3,000	3
Area 02	200	1,500	2
Area 03	200	1,500	2

For the attainment of the relation of benefits and costs (RBC), some data are needed, such as: project equipment and implantation costs, reduction of consumption and demand, tariffs of electric energy, lifetime of the project, amongst others.

A. Equipment and Implantation Costs

Table III shows the project implantation costs. The expenses quantification with man power, as well as the budget of the equipment, it was gotten together the specific products suppliers. The choice of the reservoirs and collectors took in account the availability in the Ceará's state market and the presence of PROCEL's quality stamp.

TABLE III
Implantation Costs

Item	Investment (R$)		
	Material	Man power e Administration	Total
Collecting Plates	3,360.00	336.00	3,696.00
Reservoirs	4,100.00	410.00	4,510.00
Tubing	1,000.00	500.00	1,500.00
Implantation	250.00	-----	250.00
TOTAL	**8.210,00**	**796,00**	**9,956.00**

B. Project's Annual Benefit (Y)

Table IV shows the annual benefit gotten with the solar heating project, which is calculated as shown in (1).

$$Y = 12 \times (CE \times EET + DR \times EDT) \quad (1)$$

This value comes from the electric reductions of consumption and demand, proceeding from the economy proposal. For its calculation, are variables: the conserved energy (CE, in MWh/month) and the demand reduction (DR, in kW/month) to be gotten with the implantation of the project, and the local concessionaire's energy (EET, in R$/MWh) and demand tariffs (EDT, in R$/kW) [2].

TABLE IV
Project's Annual Benefit

Item	Consumption		Demand		Y
	CE	EET	DR	EDT	
Solar Water Heating System	300	0.35	1.4	13.52	1,494.88

The consumption economy value was approached according to heating system's consumption profile, which made use of field collected data.

In turn, although the significant demand reduction proportionate by the project (approximately 30,4 kW/month), a lesser value, that was gotten through estimates, was used for the calculation of the annual benefit (1,4 kW/month), as shown in Table IV.

It was decided to take this attitude for believing to be imperceptible, at the monthly account, the total demand reduction. This, because the electric taps only works continously for a little time interval (the filling time of a 3 liters basin, or either, approximately 30 seconds), not being, therefore, perceived for the measurer, whose the sampling interval is of 15 minutes.

In case that the proposal were analyzed at the social optics instead of the consumer's optics, all the demand reduction would have to be considered.

Due to MEAC to opt for the green tariff (a tariff type existing in Brazil), the EDT (demand) is invariable during the day, not having distinction between peak and outside-peak periods.

Because the electric energy consumption by the water heating system currently in use to remain practically constant during the day, also in the peak period, as form of measure the real prevented benefit the EET was calculeted, as shown in (2),

$$EET = \frac{3}{14}CPT + \frac{11}{14}COPT \qquad (2)$$

where CPT e COPT are, respectively, the local concessionaire's consumption peak and outside-peak tariffs.

The fractions in (2) come from the MEAC's water heat system working periods: (a) total, equal to 14 hours (08:00 AM to 10:00 PM); (b) peak period, equal to 3 hours (5:30 to 8:30 PM); and (c) outside-peak period, equal to 11 hours.

C. *Annuallized Cost (K_j)*

The investment's annualized cost is calculated taking in account the equipment lifetime (n), in set with the annual interests tax (i), as shown in (3). Thus, given a present value (CPEj), the value of the annuity is calculated to amortize this value, for a period of n years and an interests tax i.

$$K_j = CPE_j \times i \times \frac{(1+i)^n}{(1+i)^n - 1} \qquad (3)$$

The present value can be understood as the cost of the equipment with the same lifetime, increased of the parcel that corresponds the other project's direct and indirect costs (administration and man power). It is calculated as shown in (4),

$$CPE_j = CE_j + \frac{(TC - ETC) \times CE_j}{ETC} \qquad (4)$$

where CE_j is the addition of the material and equipment costs with the same lifetime, TC is the project's total cost (including administration, man power and equipment costs) and ETC are the equipment total cost.

With these definitions and the values shown in Table III, it was calculated the values CPE_j and K_j shown in Tables V and VI.

TABLE V
PROJECT'S PRESENT VALUE

Item	CE j	TC	ETC	CPEj
Collecting Plates	3,360.00	3,696.00	3,360.00	3,954.16
Reservoirs	4,100.00	4,510.00	4,100.00	4,825.01
Tubing	1,000.00	1,500.00	1,000.00	1,176.83
Implantation	-----	250.00	-----	-----
TOTAL	**8,460.00**	**9,956.00**	**8,460.00**	**9,956.00**

TABLE VI
PROJECT'S ANNUALLIZED COST

Item	lifetime (years)	interests tax	CPEj	K_j
Collecting Plates	20	12%	3,954.16	529.38
Reservoirs	20	12%	4,825.01	645.97
Tubing	20	12%	1,176.83	157.55
TOTAL	**20**	**12%**	**9,956.00**	**1,132.90**

D. *Relation of Benefits and Costs (RBC)*

The relation of benefits and costs – RBC – is nothing more than the annual benefit (y) and the annualized cost (Kj) quotient, as shown in (5). With this relation, it can be verified if the benefits obtained with the implantation of the project cover the involved costs (RBC > 1).

$$RBC = \frac{Y}{K_j} \qquad (5)$$

For the projected system the calculated RBC value was 1.32, therefore bigger than 1. This value shows that the benefits to be reached with the project's implantation are bigger than the related costs, during its lifetime.

VII. CONCLUSION

The relation of benefits and cost calculation, made from the optics of the consumer, showed that the benefits to be reached with implantation of the purposed solar water heating system are bigger than the costs involved. This data are extremely important for the UFC's decision in investing or not in the implantation of the system.

However, not only to UFC this data can to interest, but also to the Energy Company of the State of Ceará – COELCE. This one is judicially obliged to invest in electric energy conservation projects and, thus, could find advantages in this project, such as: (a) an electric energy conservation investment economically viable, according to requirements of the National Agency of Electric Energy – ANEEL; (b) a positive self-propaganda for the local society, since the MEAC presents great social penetration; and (c) UFC's energy account reduction, what it would facilitate its payment.

VIII. Agreements

The UFC's Electric Energy Conservation Program – PROCEN – is thankful the support of the Energy Company of Ceará – COELCE – and the Power Plants of Brazil S.A. – ELETROBRÁS.

A special gratefulness, to the Energy Processing and Control Group – GPEC/DEE–UFC –, for the supplied data.

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X. Biographies

Celso Rogério Schmidlin Júnior, was born in Guaratuba, Paraná, Brazil, in March-1980. Graduated in UFC at year of 2003 in Electric Engineering, with emphasis in Energy Systems. Currently, he is member of PROCEN and is attending the master course in Industrial Energy Efficiency and Alternative Energy Sources areas.

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Paulo Cesar Marques de Carvalho, was born in Fortaleza, Ceará, Brazil, in April-1963. Doctor at the University of Paderborn – Germany, 1993-1997, professor of the UFC's Electric Engineering Department. Researcher in Energy Systems, with some publications in the photovoltaic and aeolian generation areas.

Tomaz Nunes Cavalcante Neto, was born in Fortaleza, Ceará, Brazil, in 1954. Master in Electric Energy Distribution at the University of São Paulo, professor of disciplines of electric energy conservation of electric and coordinating of PROCEN – UFC's Electric Energy Consumption Efficiency Program.