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Implementation Costs of Engineering Solutions in Alternative Systems-Reduction of Energy and Water Consumption in the Multifamily "Minha Casa Minha Vida" Buildings

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Abstract - The Brazilian housing sector has a deficit in its popular housing segment. People from this segment face many issues affording monthly installments and financing. This article analyses the implementation of solar collectors, photovoltaic cells, reuse water, and their impacts in the edification costs of Minha Casa Minha Vida (MCMV) type 1 building (three story buildings, seven home units) in the greater region of Belo Horizonte, MG. Even though the final percentage cost of the construction was higher than expected, it is still considered important that the Federal Government analyze the possibility of implementing these items as obligatory in the basic MCMV type 1 project, aiming at reducing the high default rates in the segment.

Keywords-*Engineering Solutions, Energy and Water Consumption, Minha Casa Minha Vida*

I. INTRODUCTION

Lately, there has been a difficulty related to water availability due to natural restrictions. Power production, in Brazil, where most of the energy is generated through hydroelectric plants, has been compromised, which impacts all population [1]. For that reason, many technologies aiming at the efficient usage of solar energy and rain water are being developed [2].

After construction, other phases (occupation, operation and maintenance of the buildings) that consistently impact the enterprise begin - and in these phases, energy and water are monthly consumed [3]. The reduction of these costs in social projects such as Minha Casa Minha Vida (MCMV), can facilitate financed payments.

Including the use of solar energy in water heating and power generation, plus the use of reuse water in the basic project of MCMV category 1 will elevate the final cost of given construction. According [4] the additional cost for inexperienced real estate developers to build sustainable enterprises ranges between 3.5% and 17.5%.

But a sustainable construction is a complex process and requires plenty of changes in execution. The idea is to utilize only three items of the sustainable construction: water heating through solar power; electric energy through photo-voltaic cells; reuse water for sealed sanitary installations. Thus, it is expected a 5% increase in the final construction cost and a possible default decrease in monthly payments of financing due to the decrease of the operational cost with water and energy. However, this project will not be able neither to test the percentage of cost reduction nor default reduction because of the impossibility to do it in a timely manner.

The main housing policy was Programa Minha Casa Minha Vida - PMCMV, launched in April 2009, sponsored by the federal government according to the Ministry of Cities, with the goal to build one million homes [5]. Data from the 2010 Demographic Census [6] show that the Brazilian housing deficit reached 5.8 million units that year, which represented 10.1% of all homes in the country. In order to minimize the quality issues concerning the lifespan of the enterprises the NBR 15.575 norm was elaborated [7].

On July 19, 2013, the NBR 15.575 came into force, consolidating that the lifespan and the performance of the buildings are of responsibility shared between constructers/developers, manufacturers, designers and residents [8]. In 2014, the MCMV guideline to focus on category 1 is announced due to the large remaining deficit [9]. Default in category 1, though, whose monthly family income is up until $ 430,81($ 1,00 US Dollar = R$ 3,71 Brazilian Real), consisted of 25% in 2015.

The following table demonstrates the percentage of monthly average expenditures of a family with undeclared formal job [10].

TABLE I. TOTAL EXPENDITURES

TOTAL EXPENSES			100,0 %	
1.	Current expenditures		93,9	
	1.1	Consumption expenditure	76,4	
		Food	14,9	
		House	30,4	
		Rent		14,3
		Maintenance		3,5
		Serviços and fees		7,9
		Cleaning items		0,4
		Appliances		1,7
		Other		2,6
		Clothing	5,0	
		Transportation	14,3	
		Hygiene and personal care	1,2	
		Education	4,8	
		Leisure and culture	2,4	
		Smoking	0,8	
		Personal services	0,8	
		Diverse expenditures	1,8	
	1.2	Other current expenditures	12,0	
	1.3	Asset increase	4,1	
	1.4	Liability decrease	1,4	

Source: IBGE - PNAD ano 2002 tabela 711

The objective of this project is to evaluate the technical and economical possibilities to implement solar collectors to heat water; photovoltaic cells and reuse water in each individual unit of these buildings.

II. METHODOLOGY

A. Methodology

The present research consists of a case study of a small three-story MCMV building, category 1, in the city of Sao Joaquim de Bicas, located in the greater area of Belo Horizonte state of Minas Geais, Brazil.

The enterprise is located next to the city center of Sao Joaquim de Bicas. The building is a three-story one, seven apartments total. Each home unit has an outdoor garage spot, demarcated on the floor, in front of the building, in a 45 degree angle, the value of each unit is $ 45.774,02. The construction started in May 2015 and is expected to be finished in June 2016 (currently running late).

The construction company responsible for it is a small one, and has 6 employees in charge: 1 engineer, 1 supervisor, 1 finishing mason, 1 brick layer and 2 assistants. In some phases there has been labor outsourcing.

The first step was to determine the direction of the building, using a compass and the information contained in the photovoltaic cells and solar collector project. The second step was to estimate both water and energy consumption. The estimate considered a 4-member family and used CEMIG and COPASA data, taking into consideration the average city consumption, then adding extra 20%. After that, it was possible to determine the storage capacity of the water tank for reuse in the garage; the storage capacity of the water tank for reuse; the capacity of the hot water reservoir; the quantity (in m2) of solar collectors; the quantity (in m2) of photovoltaic cells; the hydraulic pump capacity, etc. The third step was to research the collectors manufacturers in Minas Gerais, taking into account the delivery fees, the equipment prices, installation and necessary time to execute the services of at least three different manufacturers. The same research was done concerning the photovoltaic cells and the reuse water system.

In this way it was possible to proceed to the evaluation of both technical and economical changes. All three alterations were studied and evaluated separately.

Then, it was necessary to list the equipments and their specifications:

– 7 solar panels;

– 7 hot water tanks;

– Pipes to transport hot water to the bathrooms;

– 7 mixers;

– 7 photovoltaic cells;

– 7 AC drives;

– 7 connections until units, rain gutters;

– 1 hydraulic pump;

– 20.000 liter water tank in the garage;

– 1.000 liter water tank on the top of the building;

B. Calculus and Estimates

The project intends to attend 100% of hot water demand of the home units and 100% of the energy demands of the building and 100% of reuse water.

The estimates are based on the following:

– There are four water points - toilet, shower, the kitchen sink and the laundry sink. The reuse water is private. For the building, 100% *of total* consumption.

– There will be a significant change in the original project concerning the roof. In order to meet the proposed changes, there won't be any roof, but a waterproof ceiling for the solar panels, the hot water tanks, the photovoltaic cells, the batteries, the gutters, the pump and the reuse water tank.

– And evaluation of the water tank weight on the structure of the building was made.

III. RESULTS

Although the construction was delayed due to the economic issues the country is facing, it is possible to estimate the final costs and proceed with all the necessary analysis to determine

the relation between implementing solar collectors, photovoltaic cells and reuse water in the final cost of a category 1 MCMC building.

Figure 1. Front of the building (Source: Author, October/2015)

On table II, the detailed cost of the building, without suggested implementations.

TABLE II. TOTAL COST OF THE BUILDING

ITEM	VALUE IN $
Lot	18.848,12
Taxes / Fees	6.530,29
Topography / Poll	726,99
Expenses to begin construction	1.310,04
Projects	4.092,73
Electrical	1.956,93 + 4.038,88*
Hydraulic	1.310,21
Employees	34.050,31
Regularization	1.363,43
Materials	102.186,01
Finishing	4.545,09 + 9.424,06*
TOTAL	190.383,14

Source: Constructor's costs control
* Values in red were estimated by constructor to finish the construction

Therefore, the total cost of all 7 apartments adds up to $ 27.197,59.

A. *Suggested implementations*

1) *Solar Collectors*

A solar water heating system can be divided into three basic subsystems:

– Capitation - comprised of solar collectors where the water to be heated circles in and the connecting pipes between collectors and thermal reservoir. In case of bigger installations, a hydraulic pump is also required.

– Accumulation - its main component is a thermal reservoir, plus a complementary source of energy, like gas electricity, that will ensure auxiliary heating in rainy periods or cloudy days.

– Consume - consists of all hydraulic distribution between a thermal reservoir and the points of water consumption. A scheme of solar heating in household follows.

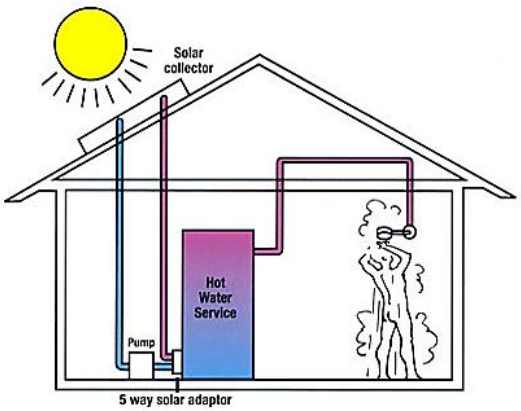

Figure 2. Solar heating layout in a residence (Source: Clean green energy zone)

An online research identified 50 companies that manufacture solar collectors for water heating. Sixteen of those companies are located in Minas Gerais, and the most competitive one, because of its delivery fees, is the one hired for the construction that concerns this present study.

TABLE III. SOLAR HEATING COMPANIES IN MINAS GERAIS

Company	Type			Speciality	
	Public	Closed	Vácuum	Manufacturer	Retailer
1		X	X	X	X
2			X		X
3			X		X
4	X	X	X	X	X
5	X	X		X	
6	X	X		X	
7			X		X
8			X		X
9	X	X	X		X
10		X	X		X
11	X				X
12		X	X	X	X
13	X	X	X		X
14		X		X	
15	X	X	X		X

The choice of a type of collector is based on the required operation temperature in determined usage, as showed in the figure below.

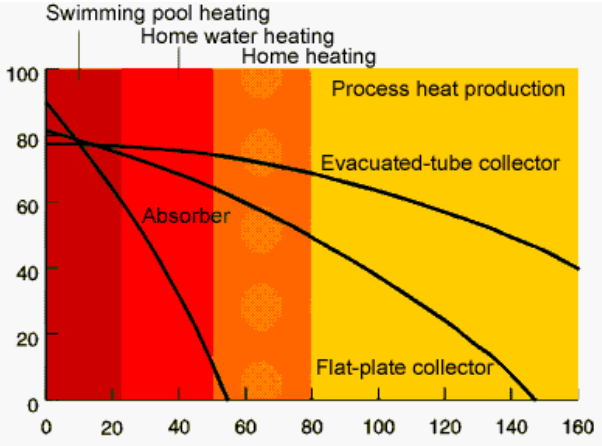

Figure 3. Solar collector type indicator (Source: David Darling)

Fifteen price estimates were collected and then analyzed. The most relevant details are listed below:

- Weight addition in each apartment's structure 250 kg;
- Shower flow rate. 8 liters per second;
- Water dealer
- PVC pipes;
- 200 liter tank for each apartment unit;
- 1 panel (1,0 x 2,0 m) for each apartment unit;
- Installation cost. $ 80,77;
- Hydraulic kit. $ 102,31;
- 200 liter tank + 1,0 x 2,0m panel. $ 457,74.

B. Photovoltaic

Photovoltaic energy conversion takes place in one single step, converting luminous energy into electric energy. According to quantum theory, the light is made up of photons that depend solely on light frequency. The energy of visible light is enough to excite electrons, confined in solids, and move them to energy levels that wouldn't be reached if they were freely moving; and in a photovoltaic device there is an asymmetry that transports the excited electrons off the body before relaxing, generating a difference in potential and feeding an external circuit [11].

The figure below illustrates the photovoltaic energy process.

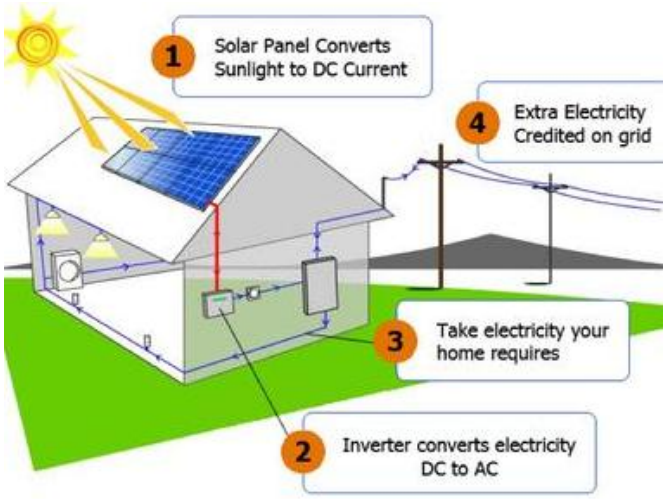

Figure 4. Photovoltaic energy scheme (Source:Kew Solar)

Five companies that acted as resellers and technical assistants for the photovoltaic system were identified in Minas Gerais, and the most competitive price was so due to the cost of the delivery fee.

TABLE IV. PHOTOVOLTAIC SYSTEM RESELLERS IN MINAS GERAIS

Company	Type			Speciality
	Connected	Isolated	Hybrid	Reseller
1	X	X	-	X
2	X	-	-	X
3	X	-	-	X
4	X	X	-	X
5	X	X	-	X

The average energy consumption in Brazilian households is about 157 Kwh/month according to the Ministry of Energy (2010). Category 1 of MCMV does not consume the same as the other classes of Brazilian society. A 35% decrease in energy consumption was estimated, which results in 102 Kwh/month.

Energy consumption for heating bathing water is at least 40%, that is, 40 Kwh/month. Therefore, the amount of energy a photovoltaic cell must produce is 60 Kwh/month. Three budgets were received. In order to produce 60 Kwh, a 0.52 kWp electric power is needed.

We will use 2 250 watts photovoltaic cells. The needed space will be 4,18 m2 they will weight 15 kg/m2. The average value investigated was $ 1.884,81. The $ 53,85 installation cost and the $ 80,77 drive cost were also considered.

C. Reuse Water

Water is more scarce every day - there is the increasing demand, its offer reduction, source pollution and population growth. One alternative for this issue is reuse water [12].

The reuse system is illustrated below:

In relation to reuse water, the steps are.

- Have a 20.000 liter tank in the garage, taking advantage of the slope/inclination;
- Estimates and budgets to dig, place water tanks and water pump;
- Place a water tank on top of the building to distribute reuse water to all apartment units;
- Reuse water will only be used in the toilet.
- In the picture below the following elements are not present, but are very important to the system:
- Filter installed before water tank;
- Pipes that will transport the reuse water to the installations where it will be used;
- Hydraulic bomb that will take water from reservoir to water tanks

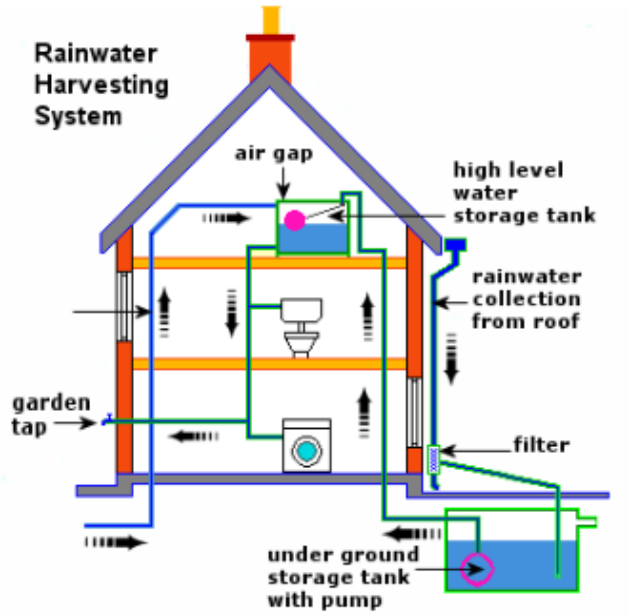

Figure 5. Rainwater harvesting system and its components (Source: Ccclab)

Only one budget was collected, but the construction company responsible for the studied buildings was contacted in order to obtain estimated values. Thus, we have two estimates. Therefore, the total cost had an average value of $ 2.732,97.

Table V reflects the impact of the solar collector (2,1 %), the photovoltaic cells (6,7%) and reuse water (1,4%) on the total cost of a category 1 MCMV building in Sao Joaquim de Bicas - MG.

TABLE V. COSTS

COTRUCTION COSTS	$ 190.383,14	89,80%
Solar Collector	$ 4.485,85	2,10%
Installation	80,77	
Kit	102,31	
Equipment + reservoir	457,74	
Photovoltaic	$ 14.136,09	6,70%
Installation/drive	134,62	
Equipment	1.884,81	
Reuse water	$ 2.732,97	1,40%
Pipe/gutter	80,77	
Garage	40,38	
Water tank	269,25	
FINAL COST	$ 211.738,07	100,00%

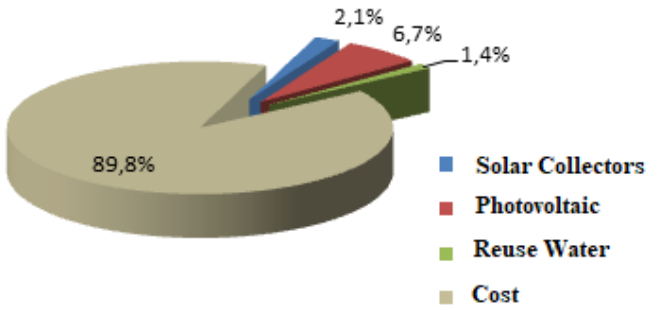

Figure 6. Reflects the impact of the solar collector, the photovoltaic cells and reuse water on the total cost of a category 1 MCMV building (Source: Autor)

IV. CONCLUSION

The impact on the final cost of the solar collector water heating system implantation was a 2.1% increase. The reuse water system also impacted the expenditures, increasing them in 1.4%. The photovoltaic cells installation meant a cost of 6.7%. These alternative systems impacted the total cost of the building in 10.2%.

The presented values show that the implementation of the suggested systems cost $ 3.050,70, which can be absorbed by the $ 6.192,95 Federal Government aid offered for category 1 MCMV buildings.

We consider the implantation of those systems not only feasible, but mandatory in the basic project of the category 1 MCMV buildings in order to reduce the operational expenses with water and energy of the residents with a restricted income. It is believed that the decrease of these monthly expenses can direct part of the family's income to the financing monthly installment.

REFERENCES

[1] BRASIL. Ministério das Cidades. Programa Minha Casa, Minha Vida - PMCMV. Brasília, 2015. Disponível em:<http://www.cidades.gov.br>. Acesso em: 15 out. de 2015.

[2] FERNANDES, A.; GUARONGHI, V. M. Energia solar. Campinas, SP, 2001. 19p.

[3] YAZBEK, P. Revista Exame: Você Paga Caro Pelo Seu Condomínio. <http://exame.abril.com.br/seu-dinheiro/noticias/voce-paga-caro-pelo-seu-condominio 2012> acesso em 01/12/2015

[4] FRANÇA, H. Custo adicional da obra é o maior obstáculo para construção sustentável decolar no Brasil. São Paulo, SP, 2013. 2 p.

[5] MOTTA, L. D. A questão da habitação no Brasil. Políticas Públicas, conflitos urbanos e o direito à cidade. Belo Horizonte, MG, 2011. 15 p.

[6] IBGE. Déficit habitacional total por situação do domicílio e déficit habitacional relativo aos domicílios particulares permanentes e improvisados. Brasil, Grandes regiões, UF e Regiões Metropolitanas. 2012.

[7] ABNT – Associação Brasileira de Normas Técnicas. NBR 15.575 – Edificações Habitacionais - Desempenho. Rio de Janeiro: ABNT, 2013.

[8] CÂMARA BRASILEIRA DA INDÚSTRIA DA CONSTRUÇÃO - CBIC. Desempenho de Edificações Habitação, 2013.

[9] BRASIL. Ministério das Cidades. Programa Minha Casa, Minha Vida - PMCMV. Brasília, 2015. Disponível em:<http://www.cidades.gov.br>. Acesso em: 15 out. de 2015.

[10] JORNAL DIÁRIO GAÚCHO. Inadimplentes terão imóveis do Minha Casa Minha Vida retomados pela Caixa. Disponível em: <http://www.jornaldiariogaucho.com.br>. Acesso em: 20 set. 2015.

[11] DIENSTMANN, G. Energia Solar – Uma Composição de Tecnologias – UFRS. Porto Alegre, 2009.

[12] SOUSA, A.F.S. Diretrizes para implantação de sistemas de reuso de água em condomínios residenciais baseados no método APPCC- análise de perigos e pontos críticos de controle: Estudo de caso Residencial Valville I/ A.F.S de Sousa – ed. XX. São Paulo, 2008. 176p.