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Lessons Learned

Sustainable solutions in social housing from the experience of the Housing and Urban Development Company of the State of São Paulo

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Sustainable solutions in social housing from the experience of the Housing and Urban Development Company of the State of São Paulo

CBCS

Companhia de Desenvolvimento Habitacional e Urbano

CDHU

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List of abbreviations and acronyms

ABES	Associação Brasileira de Engenharia Sanitária e Ambiental (Brazilian Association of Sanitary and Environmental Engineering)
ABNT	Associação Brasileira de Normas Técnicas (Brazilian Association of Technical Standards)
ABRAVA	Associação Brasileira de Refrigeração, Ar Condicionado e Aquecimento (Brazilian Association of Refrigeration, Air Conditioning and Heating)
BNH	Banco Nacional de Habitação (National Housing Bank)
CAMCS	Comissão de Avaliação de materiais, componentes e sistemas construtivos (Commission for Assessment of Materials, Components and Building Systems)
CATE	Centro de Aplicação de Tecnologias Eficientes (Center for the Application of Efficient Technologies)
CBCS	Conselho Brasileiro de Construção Sustentável (Brazilian Council for Sustainable Construction)
CDH	Companhia de Desenvolvimento Habitacional do Estado de São Paulo (Housing Development Company of the State of São Paulo)
CDHU	Companhia de Desenvolvimento Habitacional e Urbano do Estado de São Paulo (Housing and Urban Development Company of the State of São Paulo)
CECAP	Caixa Estadual de Casas para o Povo (State Economic Bank for Houses for the People)
CEF	Caixa Econômica Federal
CETESB	Companhia Ambiental do Estado de São Paulo (Environmental Company of the State of São Paulo)
CNPJ	Cadastro Nacional de Pessoa Jurídica (National Registry of Legal Entity)
COMGÁS	Companhia de Gás de São Paulo (Gas Company of São Paulo)
CODESPAULO	Companhia de Desenvolvimento de São Paulo (Development Company of São Paulo)
CONPET	Programa Nacional de Racionalização do Uso de Derivados do Petróleo e do Gás Natural (National Program for Sound Use of Oil and Natural Gas)
COSIPA	Companhia Siderúrgica Paulista (Steel Company of São Paulo)
CPFL	Companhia Paulista de Força e Luz (Light and Power Company of São Paulo)
DAEE	Departamento de águas e energia elétrica (Water and Electrical Energy Department)
EPS	Expanded polystyrene
FPHIS	Fundo Paulista de Habitação de Interesse Social (São Paulo Social Housing Fund)
ICMS	Imposto sobre Circulação de Mercadorias e Prestação de Serviços (State VAT – Value Added Tax)
INMETRO	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (National Institute of Metrology, Standardization and Industrial Quality)

IPT	Instituto de Pesquisas Tecnológicas (Institute of Technological Research)
ISO	International Organization for Standardization
LABEEE	Laboratório de Eficiência Energética em Edificações (Building Energy Efficiency Laboratory)
NGO	Non-governmental organization
PLC	Power Line Communication
PBE	Programa Brasileiro de Energia (Brazilian Energy Program)
PBQP-H	Programa Brasileiro de Qualidade e Produtividade do Habitat (Brazilian Program for Quality and Productivity of the Habitat)
PCI	Programa de Conservação de Insumos (Program to Conserve Inputs)
PMH	Programa de Mutirão Habitacional (Program of Housing Community Taskforce)
ProAcqua	Programa de qualidade e produtividade da medição individualizada de água (Program for quality and productivity of individual water metering)
PROCEL	Programa Nacional de Conservação de Energia Elétrica (National Program for Electricity Conservation)
PVC	Polyvinyl Chloride
QUALIHAB	Programa de Qualidade na Construção Habitacional do Estado de São Paulo (Program of the State of São Paulo for Quality in Housing Construction)
QUALISOL	Programa de Qualificação de Fornecedores de Sistemas de Aquecimento Solar (Qualification Program for Suppliers of Solar Heating Systems)
QUALINSTAL	Programa de Qualificação de Empresas Instaladoras (Qualification Program for Installers Companies)
SABESP	Companhia de Saneamento Básico do Estado de São Paulo (Basic Sanitation Company of the State of São Paulo)
SENAC-SP	Serviço Nacional de Aprendizagem Comercial do Estado de São Paulo (National Service of Commercial Education in the State of São Paulo)
SFH	Sistema Financeiro de Habitação (Housing Financial System)
SH	Secretaria de Habitação (Housing Secretariat)
TV	Television
Senac	Serviço Nacional de Aprendizagem Comercial do Estado de São Paulo
UFSC	Universidade Federal de Santa Catarina (Federal University of Santa Catarina)
UNEP	United Nations Environment Programme
Unicamp	Universidade Estadual de Campinas (Campinas State University)
USP	Universidade de São Paulo (São Paulo University)

Summary

The United Nations Environment Programme (UNEP) launched the SUSHI project - Sustainable Social Housing Initiative - with the objective to create guidelines for the inclusion of sustainable elements in social housing projects. São Paulo City has been chosen by UNEP as one of its pilot sites for development of a local approach to promote sustainable technologies and strategies in social housing projects.

During this project, the local project team, under the leadership of the Brazilian Council for Sustainable Construction (CBCS), executed the following activities:

1. Assessment of the status of social housing in the State of São Paulo as a case study, including conceptualization of sustainability and the items to be verified for the proposal of sustainable alternatives; results of this study are found in the report titled "Mapping of key stakeholders and processes that affect selection of solutions (technologies and materials) for social housing projects."

2. Assessment of the initiatives already conducted by CDHU to integrate sustainable elements in social housing projects, including for example, replacement of equipment, modification of buildings´ design or provision of alternative sources of water/energy. The results of this assessment are incorporated in this report.

3. Based on these two reports, the team summarized the results in the report "Assessment of market-available technologies and solutions to improve energy efficiency and rational use of water in social housing projects in Brazil", that emphasizes potential technologies and design modifications that could be applied to social housing projects. It provides an analysis of costs, benefits and efficiency of the alternatives selected to improve the sustainability performance of social housing units.

The main objective of the SUSHI project team is to map, organize and define the essential sustainable technologies to be incorporated into the conception of social housing projects in Brazil, taking into account all stakeholders involved in this process, such as consumers, suppliers and, especially, project developers.

Due to the rapid urbanization and population growth, the building sector faces an increasing demand, particularly in developing countries. Considering that the building and construction industry is one of the main sectors contributing to the emission of greenhouse gases responsible for climate change, research on sustainable construction techniques is becoming increasingly relevant.

This report discusses the existing technologies related to rational use of water and energy efficiency, based on the experience of the Housing and Urban Development Company of the State of São Paulo (CDHU), the largest social housing developer in Brazil.

To assess actions related to energy efficiency, discussions focused at first on architectural design and construction issues (such as standardization of a minimum ceiling height, use of roof lining, use of metallic structure and tiles for roofs, as well as use of thermal properties of coverage materials, types of frames that can improve the thermal performance of housing and natural shading). The team then considered actions for energy efficiency that require a change in auxiliary equipment (solar and gas water heating, use of energy-efficient appliances, use of photovoltaic energy, or remote measurement of energy inputs).

In terms of actions related to rational use of water, this report addresses individual and collective measures, including individualized water metering, rainwater harvesting for non-potable use, use of water-saving equipment and appliances, phyto-treatment of wastewater, in-situ sewage treatment, and use of permeable pavement.

In addition to these items, this report describes additional experiences related to landscaping, alternative building materials and social interventions from CDHU.

Each CDHU experience was reported according to the following outline, in order to facilitate understanding and subsequent consultation:

a) System definition;
b) History of intervention;
c) Results;
d) Challenges.

Furthermore, this report presents results of two costs simulations conducted in order to evaluate the costs increase in a standard CDHU housing unit when

certain sustainable strategies are implemented. The study highlights potential benefits of the solutions for energy efficiency and water management, proposing recommendations of actions that impact the supply and demand of these solutions and allow improvement of the unit performance as well as of the quality of life for residents.

From the experience reported by CDHU, it was possible to understand some of the difficulties encountered in the application of new technologies, since there is still a social barrier and consumers´ resistance towards the use of some equipment. User involvement and an integrated assessment of the economic, social and environmental conditions proved to be two key components of a successful initiative. This is especially important when the technological improvement or alternative equipment require the user to operate or maintain a system, or modify their lifestyles.

Although this reports highlights challenges encountered in the pilot testing of alternative solutions, it also shows that their application has delivered predominantly positive results, both in terms of environmental impact, and in terms of social and economic repercussions. This stimulates the continuity of research and testing to include sustainable solutions in social housing units in Brazil.

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Introduction

This report was developed by the team of the Brazilian Sustainable Construction Council (CBCS) in collaboration with experts and representatives of the Housing and Urban Development Company of the State of São Paulo (CDHU) and the Housing Secretariat of the State of São Paulo. Between 2009 and 2010, the CBCS team conducted documentary research, interviews and consultations with experts in order to identify available technologies and strategies to improve energy efficiency and water management in social housing projects in the State of São Paulo.

The first result of this research was a mapping of the sustainable solutions available on the market and potentially applicable to social housing projects. The team conducted a first analysis to assess the costs and benefits of these solutions based on local context. During this evaluation, conducted in cooperation with local actors, CDHU expressed the need to conduct an assessment of its previous experiences in promoting sustainability in social housing projects, in order to understand their success or failure, verify whether these actions could be replicated, and identify potential improvements for future implementation.

The objective of this report is to conduct a survey and technical assessment of the sustainable practices and technologies tested by CDHU in social housing projects.

The CDHU is a company of the State Government, administered by the Housing Secretariat. Its goal is to develop housing programs throughout the state of São Paulo exclusively for the low-income population.

The Housing Secretariat is responsible for execution of the housing policies of the State of São Paulo, establishing goals and guidelines and developing specific projects. The initiatives mentioned in this report focus on improving the energy efficiency and the use of water in social housing units. They are part of the Program for Insertion of Socio-environmental Guidelines in the CDHU Projects, developed between 1999 and 2003.

The survey aims at providing information about the technologies and practices tested, reporting cases of success or failure and, through the acquired knowledge, providing guidelines and recommendations for future projects. These guidelines would contribute to the development of better practices and results in the process of application of sustainability concepts in social housing projects in Brazil.

This report starts by describing the company's history, as well as its activities and role in promoting construction of social housing in the State of São Paulo. Chapter 2 describes various sustainable technologies and actions adopted by CDHU in its projects, focusing on the proposals that target energy efficiency, rational use of water and social issues.

Chapter 3 provides an assessment of the additional cost related to the use of alternative solutions, for different types of standards CDHU units. Finally, Chapter 4 highlights the main points to be considered in order to improve future actions related to the implementation of sustainable solutions in social housing, indicating the potential socioeconomic benefits. In addition, this chapter summarizes recommendations to improve the management of water and energy demand and supply.

1 Background and methodology

1.1 CDHU History

The Housing and Urban Development Company of the State of São Paulo (CDHU) is a company of the State of São Paulo Government. It pertains to the Housing Secretariat, and is considered the most important state-level agent promoting social housing in Brazil. With financial transactions of about U$ 350 million per year, a budget substantially higher than the income of most of the municipalities of São Paulo and of at least 15 Brazilian states, CDHU is today one of the biggest housing companies in Latin America. Its purpose is to develop housing programs all around the State of São Paulo, targeting exclusively low income population, which includes families with income in the range of 1-10 minimum wages[1]. CDHU also intervenes in the urban development of cities, following the Housing Secretariat guidelines.

The CDHU emerged from the transformation of the government agencies of the state of São Paulo created to meet housing demands. CECAP (State Economic Bank for Houses for the People) was the first institution of the state of São Paulo, created in 1949 under Law No. 483, in order to produce dwellings for a growing population concentrating in cities because of the strong industrialization after World War II. In 1964 it was regulated by the implementing decree No. 43.107 and subordinated to the Labor, Industry and Commerce Secretariat. In 1968, Law No. 10.262 allowed CECAP to use resources from the Housing Financial System (SFH), under the National Housing Bank (BNH).

In 1975, through Law No. 905, CECAP came to act in a more specific sector, the low income sector, changing its name to State Popular Housing Company. The objective of the change was to speed up the production of houses, because as the company was under the Interior Secretariat, it could directly administer the financial resources from BNH.

In 1980, CECAP was closed down through Decree No. 29.335, and it was reopened with the name CODESPAULO (São Paulo Development Company) in 1981, linked to the Science and Technology Secretariat.

In 1983, the Executive Housing Secretariat was created, through Decree No. 21.592, subordinated to the state governor. In 1984, Decree No. 22.061 altered the name of CODESPAULO to CDH (Housing Development Company of the State of São Paulo). A new operation profile was established, using the resources of the state Treasury to build partnerships with municipalities in joint community effort programs. In 1987, with the dissolution of BNH, the Executive Housing Secretariat was renamed to State Housing Secretariat, starting a period of progressive strengthening of the housing policy to meet demands for dwellings.

Finally, in 1988, the Housing Secretariat was closed (as was the Metropolitan Affairs Secretariat), and the Urban Development and Housing Secretariat was established, responsible for formulating housing and urban policies. CDH came to be called CDHU, Housing and Urban Development Company of the State of São Paulo, absorbing the prior organizational structure and that of other institutions. It started to operate as it is known today, being responsible for executing the urban and housing policy of the State of São Paulo.

1 The monthly minimum wage in Brazil is about US$ 300.00, according to exchange rate of December 22nd, 2010.

1.2 Resources and evolution of CDHU actions

Until the early eighties, funding for housing policies of the state of São Paulo was made available through the Housing Financial System (SFH). With the enactment of Law No. 6.556, from November 30, 1989, budgetary funds were made available to CDHU from the state Government, as a result of the 1% increase in the ICMS rate (value-added tax).

In 1997, the additional ICMS resources were removed and funds for the CDHU became a commitment of the Executive Government.

Installments paid by borrowers are another important source of resources for housing investment. They corresponded to approximately 12% of this investment from 1995 to 2007.

In the current administration, some partnerships have become significant fundraising sources. The federal government expanded its investments into housing through partnerships with state governments. In particular, the partnership signed with the Federal Government through Caixa Economica Federal (Federal Savings Bank) allows the Housing Secretariat to provide grants to complement the amount required to develop the projects presented by Associations and Cooperatives. This initiative fits under the Federal Government's Programs Credito Solidário[2] and Minha Casa Minha Vida[3] .

Furthermore, in 2008, through state Law No. 12.801, the government of the state of São Paulo joined the National Social Housing System, leading to the creation of the São Paulo Social Housing Fund (FPHIS) and of the Housing Guarantee Fund, responsible, respectively, for establishing guidelines and criteria for the implementation of housing policies for low income families and for credit and securitization operations.

In 1988, with the increased funding for urban and housing policies resulting from the increase of 1% in the ICMS (State VAT), CDHU started to carry out a large scale housing policy. During this new phase, the company consolidated a diversified production structure of housing projects, including contracting of construction companies and partnership programs with municipalities and with local community associations.

In order to manage the significant growth in the number of housing developments and ventures, the company adapted its organizational structure through a process of progressive outsourcing of the execution of architectural and urban planning projects, management and oversight of the activities, provision of services to the beneficiaries, legal support, etc. In this way, the company's own staff took over the task of managing the contracts of the implementing companies, while continuing the activities of conception and analysis of architectural and urban planning projects, development of housing programs, housing planning and management of contracts with the social housing residents.

The practice of mass production of housing, driven by the search for low cost solutions, did not always achieve satisfactory results, in terms of quality and urban insertion.

Due to the company's existing practices, many of the units were delivered to beneficiaries without meeting the terms and conditions required for regulation by public agencies. This led to a situation of predominance of unregulated and unregistered housing units. This situation was negative for the beneficiaries of the housing programs, since owners were not able to legally register their properties and obtain the deeds. It also led to losses for condominiums and utility companies in the management of water, lighting and energy bills, particularly when beneficiaries of social housing defaulted on their bills. Significant efforts were required to reverse this situation.

From the mid-nineties, the CDHU started to diversify its operation and invest into improvement of its products. Concerns over industrialization and improvement of the construction quality lead to the creation of a state quality system, the QUALIHAB Program, in 1995, as well as to the increasing emphasis placed on the employment of qualified workforce, namely for construction works in the community associations´ programs.

At the same time, the provision of housing was more often related to the response to urban and socio-environmental needs. New programs focused on resettling populations living in preserved or hazardous areas, urbanization of slums, work with the population living in slum dwellings, and provision of services for the indigenous and quilombola[4] populations.

The CDHU housing projects began to focus more on socio-environmental and urban qualification aspects, no longer on simple investment into housing. The company expanded its investments into equipment and urban infrastructure projects. Today, all properties must be registered before keys are handed to the owners, formalizing the links between beneficiaries and their properties and the urban environment, with the objective to improve urban management.

2 Caixa's line of credit for low-income populations to buy their own house

3 The program aims at the construction of housing units, which once completed are sold without any prior lease to families who have income up to R$ 1,395.00.

4 Quilombols are ethnic community settlements. Most were created in the 19th century by fugitive African slaves.

1.3 Integration of sustainability in CDHU management

The concept of sustainable development is based on the search for viable solutions that meet needs of the present generation without compromising those of future generations.

To incorporate this concept, CDHU seeks to adopt an integrated vision of the environmental, economic and social dimensions of housing. CDHU has conducted a series of pilot experiences to integrate various aspects of urban planning and design of housing units. In the current administration, the Housing Secretariat and the CDHU incorporated sustainability concerns as a criterion for the development of their actions along three lines:

1. Reversal of social and environmental passive (actions in slums, recovery of protected areas – e.g. the actions in Serra do Mar - regulation of lands, improvements in existing housing units, etc.)
2. Sustainability of the product through state housing policy (product improvement, adoption of new housing standards, adoption of the Universal Design guidelines, etc).
3. Socioeconomic sustainability for the population (creating capacity for maintenance and using benefits of housing services, with socio-organizational work, promoting income-generating actions, subsidies, etc).

1.3.1 Reversal of socio-environmental passive through urban planning

From the seventies to the mid-eighties, land for social housing was generally selected based on its cost, which led to the appropriation of city areas that were not always suitable for urban insertion, and were characterized by lack of public services and equipment.

Since the mid-nineties, the CDHU started to improve its land selection criteria, including determinant factors that sought to ensure access to urban benefits for future residents. Today the criteria are:

- Provide the future dwellings´ population not only with a housing unit of appropriate construction quality, but also with access to public infrastructure, trade and services inherent to the housing function, in order to integrate the resident families to the municipality's urban structure;
- Minimize public investments either in the execution of infrastructure works or in the implementation of social infrastructure in new areas;
- Avoid additional pressure on available infrastructure;
- Optimize land use, respecting regional characteristics and land suitability to intended occupation and integration with surrounding areas;
- Support the development of projects that are based on reliable technical, urban, physiographic, environmental, legal and land tenure information; this information will contribute to the development of the project and to a faster approval and registration of the units.

CDHU is currently concentrating on interventions in urban environmental recovery and regulation of existing settlements. Its largest project in this area is the Program for the Socio-Environmental Recovery of the Serra do Mar and the Mosaic Systems of the Atlantic Forest. CDHU has two possibilities to acquire land:

a) Acquisition by land donation: medium and small municipalities normally provide the land. In these cases, the company carries out technical evaluation of the soil, mainly in its urban and legal aspects. If accepted by the company, the local government donates the land to build the housing complex. Donation of the land increases the feasibility of the project, because the cost of the housing unit is reduced.

b) Acquisition by land purchase: the company acquires the land on the market. In large cities, such as in the Metropolitan Region of São Paulo[6] , the cost of land is higher than in medium and small cities. Therefore, the investments required are much higher, which makes the financial viability of the project more complicated, in terms of implementation costs, capacity of the families to pay and government subsidies. This is a challenge for social housing development in larger cities.

One of the options for reducing costs is to build multi-family buildings, reducing the unit price. In areas where land is cheaper, such as small towns, individual houses are generally preferred.

6 The Metropolitan Region of São Paulo counts 39 municipalities and a population of about 20 million, which corresponds to almost half of the total state population.

1.3.2 Product Sustainability

CDHU used to carry out the planning of the projects with its own architects and engineers. Given the large construction volume, this was altered during the last decade. Today, most of the design, construction, and management activities are outsourced or sub-contracted.

Another aspect to be highlighted is that most of the social housing projects in Brazil were produced according to standardized project solutions for single family houses or multi-family buildings. The aim of standardization was to control construction costs. However, the needs of users and regional climate characteristics were not taken into consideration, leading to major distortions in project performance.

CDHU is currently working on the diversification of typologies, for instance including a third bedroom, increasing the floor area from 42 m^2 to 64 m^2, adapting design for disabled population and those with mobility problems through Universal Design and using sustainability standards for energy efficiency and eco-efficiency of housing solutions.

1.3.3 Socio-economic sustainability

CDHU aims at the socioeconomic development of the beneficiaries of housing services. To this end, CDHU has invested into social aspects, administration during the pre-occupation and post-construction period and interventions to recover unsafe settlements. Due to the importance of these projects, they are addressed in detail in item 3.6.

In addition to these initiatives, CDHU provides subsidies for low income populations according to Law No. 6556, from 1989. CDHU is able to finance construction with low interest rates to meet the needs of families that earn from 1 to 10 minimum wages, giving priority to those earning from 1 to 3 minimum wages. Furthermore, it has adopted a cap on installments, based on family income, as shown in Table 1 – Relation of upper limit of income commitments with the family income.

Table 1 – Relation of upper limit of income commitments with the family income

Family Income (no. of minimum wages)	Upper Limit of Income Commitment
1 to 3	15%
3 to 5	15% to 20%
5 to 8.5	20% to 25%
8.5 to 10	25% to 30%

Source: CDHU/DAF (2010)

1.4 Sustainable innovations and methodology for pilot project analysis

1.4.1 Adoption of sustainable technologies

Throughout its existence, CDHU developed projects and actions (on a pilot scale) to allow the incorporation of alternatives that could be more sustainable, particularly in the areas of water and energy consumption. As a rule, CDHU sought and seeks to add new equipment and technologies to its housing units in order to provide the aforementioned gains.

In addition to using the financial resources made available by the state to implement programs for technological innovation and improvement, several technologies evaluated by the CDHU were introduced by private companies interested in the application of their technologies in social housing.

One of the challenges for inserting these new technologies is their maintenance and conservation. Besides the technical evaluation of the performance of the innovations and improvements, CDHU is interested in their adaptation to the profile of its housing services. The following questions must be considered: Is the technology easy to use? Is it easy to maintain? Is it accessible? What is the behavior of residents in a post-occupation evaluation?

Regarding the adoption of sustainable technologies, the practice of CDHU is firstly to test actions as INNOVATIONS in pilot projects and, if successful, transform them into a CDHU STANDARD, adopting them in all developments. In some cases, CDHU was successful in implementing these technologies, but in others, it experienced difficulties and those technologies are no longer used.

In order to improve the acceptance by the user, from now on, CDHU will include in its public tenders educational projects for users to show them the economic savings and teach them how to use and maintain the technologies implemented in social housing unit.

Table 2 - Innovations tested by the CDHU and public policies adopted - shows the innovations tested by the CDHU throughout its history and the actions that, up to now, have turned into CDHU standards.

Each of these actions will be discussed in detail in chapter 2, describing lessons learned in the areas of water and energy, and in some correlated areas such as landscaping, design solutions and social action. The methodology employed in the analysis is clarified below.

Table 2 - Innovations tested by the CDHU and public policies adopted

INNOVATION	CDHU STANDARD
Solar heater	YES
Gas Heater	NO
Solar-electric hybrid heater	YES
Shower timer	NO
Efficient electrical appliances and equipment	NO
Photovoltaic energy	NO
Remote metering	NO
Use of roof slab and lining	YES
Use of ceramic roofing tiles	NO
Use of steel roof structure	YES
Individualized water metering	YES
Rainwater harvesting for reuse	NO
Water saving devices	YES
Phyto treatment	NO
In situ sewage treatment	NO
Permeable pavement	NO
Natural shading	NO
Modulation	NO
Electrical and water kit	NO
QUALIHAB	YES
Concrete walls cast in loco	NO
Laminar buildings	NO
Universal Design	YES

Source: Survey of CDHU data/2010

1.4.2 Methodology for survey and analysis of the technologies used

The survey and analysis of the data on the technologies already in use by CDHU were carried out through interviews with CDHU technical staff and through bibliographical references supplied by the company technical staff. Some essential items were defined for carrying out the mapping of solutions in an organized fashion, facilitating subsequent research on the issue. Below is a description of the mapping items:

a) System description:

This item gives an overview of the solution with regard to the products, technologies and solutions available on the market, describing the main characteristics of their operation, construction aspects, implementation and maintenance costs, among other relevant data.

b) History of implementation:

This article describes the first locality where the technology was installed and tested in housing complexes of CDHU and how the first use of the described solution ran, as well as the name of the housing development, the involved population, place and date of implementation of solution.

c) Results:

The benefits and main difficulties encountered during the use of solution are described, considering technical aspects, such as implementation, maintenance, as well as generated costs and social impacts.

d) Challenges:

This item describes the main challenges for the adoption of the solution as a public policy and what could be improved in its application in other CDHU housing developments.

2 Lessons learned

2.1 Energy efficiency and thermal comfort

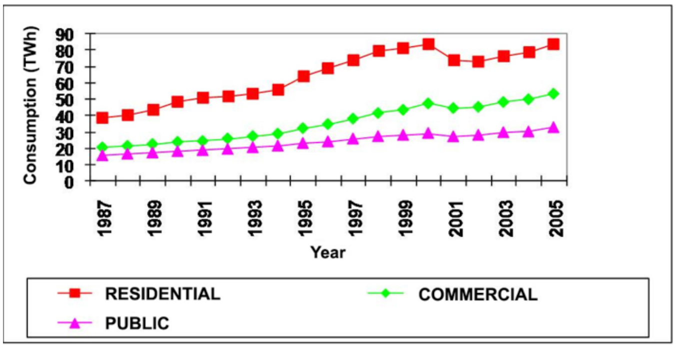
The consumption of electricity in Brazil grew approximately 30% in the second half of the nineties, culminating with the Brazilian energy crisis in 2000 (Figure 1). It was therefore necessary to create measures to contain consumption and to seek sustainable technological solutions to cope with the growing energy demand.

In this regard, Law No. 10,285 from 2001 (Energy Efficiency Act), was an important milestone for Brazil, in that it established the National Policy for Conservation and Sound Use of Energy, with the aim of promoting energy efficiency in the country.

According to CDHU, until the year 2000, the share of residential consumption in the national consumption stayed around 33%. It decreased until 2003, when it reached 26.4% of the national consumption, possibly as a result of the contention measures implemented, and then started increasing again. The reduction of electricity consumption in households is an important issue for energy consumption in Brazil, given its percentage in current and predicted future consumption and considering the current housing shortage.

In order to reduce consumption, investments that are not always available to the public administration are necessary. Therefore, to enable these investments, in addition to the funds made available by the state to implement energetic efficiency programs, CDHU took a proactive stance with the electricity companies which, since their privatization, are obliged to invest 0.5% of their revenue in energy efficiency actions. In this way, CDHU propitiated a useful partnership, since the company was seeking investments for energy efficiency and the concessionaires, who are obliged to invest, found in the construction works of the CDHU the necessary volume and place for the actions required by law. CDHU received resources from the energy distribution companies, obliged by law to invest 1% of their net revenue in these programs. Furthermore, it received donations from private sector companies interested in disseminating their technologies, for instance in the case of solar water heating systems.

Figure 1 - Growth in the consumption of electricity in the residential sector.



Source: BEN (NATIONAL ENERGY BALANCE), 2007.

2.1.1 Solar and Gas water heating solutions

Hot water generation is the process of heat transfer from an energy source to obtain water at a certain temperature, with or without storage of the volume being heated (ILHA et al., 1996). Hot water systems for buildings can be classified, according to Ilha et al. (1996), in:

- Individual - consisting only of one point-of-use without the need for a hot water network. An example is the electric shower.
- Private networks - using equipment for heating water and a network of pipes to distribute the heated water to several points-of-use in the same housing unit. An example is the gas heater, available in every residential unit, that can be function with or without a tank (instantaneous) and may be associated to solar energy. For these heaters, hot and cold water is mixed at the point-of-use, allowing each user to determine temperature and flow for their comfort.
- Collective networks, when a device generates hot water and distributes it through a network of pipes that conduct the heated water to several points-of-use in more than one housing unit. An example is the boiler system, where hot water is generated outside of the residential unit.

The various types of water heating systems produce different levels of comfort for the final user. The individual system, having a lower heating capacity and flow, can provide a lower comfort level than a centralized system (ILHA et al., 1996).

Solar and gas heaters in centralized systems allow for a greater flow and, consequently, greater bathing comfort when compared to the electric shower heads, which can reach flows of up to 0.05 L/s for 4.4 kW, and are the business-as-usual in social housing (PRADO; GONÇALVES, 1998). Some electric shower heads have higher performance, with flows similar to solar and gas heaters. But with the same bathing time, energy consumption and related environmental impact are greater than for other systems (TABORIANSKI, 2002).

On the other hand, greater comfort can increase bathing time (estimated by Prado (1991) to be 7 minutes for social housing using electric shower heads) which would increase water consumption in gas and solar heaters, as already observed by the CDHU project team.

This comparison shows the importance of capacity building of the final user. It must be made clear that water resources are being consumed as well as the energy source (electric, gas, solar). It is necessary to find a balance point between user bathing comfort and low water and energy consumption.

According to CDHU (2008), water heating systems in the housing units may use gas (natural or LPG) or solar energy. If a public gas system exists in the area of the undertaking, heating should be done with natural gas and not with LPG. On the other hand, adoption of solar heating systems can only be approved after a study of the sunshine rate of the area and the feasibility of placing the collector panels appropriately.

Finally, for housing units, hot water should only be supplied to the shower, which should have a water mixer with two pressure valves. CDHU initiatives in the area of water heating are presented below.

2.1.1.1 Solar water heating

a) System definition

According to ABNT NBR 15569 (2008), a solar heating system is composed of a solar collector, thermal reservoir, backup heating, accessories and hydraulic interconnections. The solar collector is a device for absorbing the greatest possible amount of solar energy and transferring this radiation to a fluid. Collectors should have the following characteristics:

- Resistance to external conditions (marine environments, dust, snow, hail, etc.) and high and low temperatures;
- Efficiency in energy conversion for the intended use.

The reservoir is needed due to the fact that the demand for hot water does not usually coincide with the sunshine period. In the case of residential housing, hot water consumption occurs principally from 18:00 to 20:00 hrs, but the generation of hot water by the solar heater occurs during the day.

In most cases, solar heating systems include an auxiliary energy source, usually gas or electric, to supply energy in days with no or insufficient sunshine, and a hot water distribution network. Thus, hybrid solar-gas or solar-electric systems can be adopted.

There are different types of electrical equipment that can be used together with solar heating systems. They can be internal thermal resistances in the boiler that can be turned on, manually or automatically, through thermostats and timers; or point-of-use electrical devices. The point-of-use devices include electric shower heads, which can have fixed or variable power settings. The latter can be adjusted manually or automatically, where temperature and water flow are controlled without user input.

Regarding the solar heating system typologies, five factors are considered (SOUZA; ABREU, 2009):

- Individual or collective systems: single family houses use individual systems, multi-family can use either.
- Central or instantaneous backup heating: for electric central backup heating, an electrical resistance is placed in the boiler and its main advantage is lower wattage, while the main disadvantage is greater energy consumption in comparison to instantaneous heaters. This arises from the need to maintain the thermal reservoir heated to a temperature that ensures bathing comfort. Complementary electric instantaneous heating systems generally use electric shower heads.
- Natural (passive) or forced (active) circulation systems: the natural circulation system (thermosiphon) is the one installed in most single family solar heating systems in Brazil. The efficiency of this system is lower than that of forced circulation systems. In multi-family housing, when larger scale solar heating systems are used, forced circulations systems are preferred, since there is a significant gain in system performance and decrease in maintenance costs as these are divided among the various owners.
- Indirect or direct circuits: The difference between solar heating systems with direct and indirect circuits is whether an intermediary heat exchanger exists between the collector panels and the thermal reservoir. Direct circuits are usually more efficient.
- With or without pipe circulation ring: A hot water pipe loop can link the thermal reservoir to the point-of-use and back to the thermal reservoir. The basic function of this ring feed is to avoid waiting times for bathing in points-of-use that are far from the thermal reservoir. This kind of solution increases the thermal losses of the system and the global cost of installation, but avoids water wastage. In general, feed rings are used in multi-family housing with a collective solar water system.

Thus, the awareness of the type of solution and components, besides comfort and resource consumption assets, is essential for choosing an appropriate system option. Basically, the solar water heating systems can have four different configurations (PRADO et al., 2005):

1. Direct Passive System: water is heated directly by the collectors and is circulated with the aid of a thermosiphon, that is, the difference in density due to the temperature variation between the collectors and the reservoirs creates a pressure gradient that moves the fluid. Due to its simple operation, this is the most used water heating system for domestic purposes, although large distances or detours in the pipe work are to be avoided to facilitate the flow of water in the system. The reservoir must necessarily be placed above the level of the solar collectors so that the density difference can ensure the natural circulation of water. In this type of system, the reservoir is usually located in an open area, with no protection against bad weather, which may reduce the durability of the equipment, even with a protective cover.
2. Indirect Passive System: a refrigerant receives thermal energy in the collector and transfers it to water in a heat exchanger. Circulation of the fluid is carried out with the aid of a thermosiphon and the heat exchanger may, or may not, store a certain volume of hot water. The indirect system is usually only used when protection against cold severe climate conditions is needed, because it is very costly.
3. Direct Active System: water is circulated with the aid of a pump and is heated directly by the collectors. Since a pump is used to circulate water, the reservoir can be placed anywhere with respect to the collectors. The pump starts when the temperature difference between the upper part of the collector and the reservoir reaches a predetermined level. It is disengaged when this temperature difference is small or when the reservoir water reaches the desired temperature. The pump is also used as protection against freezing when the external temperature reaches critical levels. Protection against freezing can also be achieved by draining the water in the collectors.
4. Indirect Active System: water is circulated with the aid of one or two pumps, depending on the heat exchanger used, and a refrigerant receives the thermal energy in the collector and transfers it to water in the heat exchanger. The heat exchanger, which transfers the heat of the refrigerant to water, can be outside or within the reservoir, both having positive and negative aspects. When the heat exchanger is outside the thermal reservoir, it allows for greater flexibility but leads to larger heat losses. This type of system is used in regions where the danger of water freezing in pipes is high.

According to Souza; Abreu (2009) before installing solar heating systems in social housing, the various available options, their costs and expected performance must be analyzed.This is even more important when the price of the solar heating system is fully transferred to the borrowers through house financing, since the natural tendency of lowering equipment costs to decrease the borrower's installments may lead to a worse solution, in terms of the economic feasibility of these systems.

The authors believe that the projects of a nationwide scale generally seek to standardize equipment and installation designs in order to reduce initial and operational costs. Although this is logical, it is limited by specific characteristics of the various types of undertakings that will receive a solar heating system. A series of factors will have strong influence on program results. These include building type of the solar heating system, consumption profiles, local climate, technical characteristics of the installation, etc.

In CDHU projects, the solar-electric hybrid systems have been used, which is a system composed of a solar heater and an electric shower head, as a backup system for days of little sunshine, which can be adjusted manually or automatically, in the latter case controlling temperature and water flow without user input.

The solar heating system for single family houses or 2-story houses must be comprised of collector panel(s) and storage reservoir(s). The circulation system generally makes use of a thermosiphon. Whenever a circulation pump is needed, it must be justified in the planning worksheet. If the solar system used in CDHU multi-family buildings is individual, that is, one heater per apartment, attention should be paid to system maintenance, since it will no longer be under the care of the building manager but of the individual owners. In multi-family buildings, where a collective heating system is possible, planners, together with the CDHU, must seek a solution to have individual consumption metering (CDHU, 2008).

Figure 2 – Housing development in Cafelândia with solar heaters.

b) History of implementation

The first CDHU experience in installing solar water heating systems in horizontal residential developments was in Cafelândia C, in the town of Cafelândia[7], in the region of Bauru, which had already been built when the solar heating systems were installed. This development has 136 houses, built through joint community effort, and is situated in Vila Belém, in the Cafelândia municipality. The weather in this city is hot, with a dry winter. The average maximum temperature is 36°C and the average minimum temperature is 12° C. This means that less hot water is required for bathing. The work began in 2000 and was concluded and delivered to beneficiaries in 2005. Figure 2 and Figure 3 show the details of the systems installed in this development.

The system used in Cafelândia was donated by the company who provided the solar equipment, and was installed by the community after being trained by the manufacturer. Since the system was installed after the houses had been built, this option was chosen as it does not require opening the walls.

The system was composed of a solar collector (Figure 4), a thermal reservoir (Figure 5), installed under the roof inside the building (Figure 6) and a backup system using an electric shower head, configuring a solar-electric hybrid system. In this case, the electric shower head supplied the necessary electric resistance to heat water in days of little sunshine or until the water heated by the solar system arrived. This shower head had a manual control and was to remain switched off and only be turned on when the solar radiation was insufficient to heat up the water.

Figure 3 – Detail of the heater installation in Cafelândia.

7 Cafelândia is located at northwest region of the state of São Paulo and has about 16,000 inhabitants.

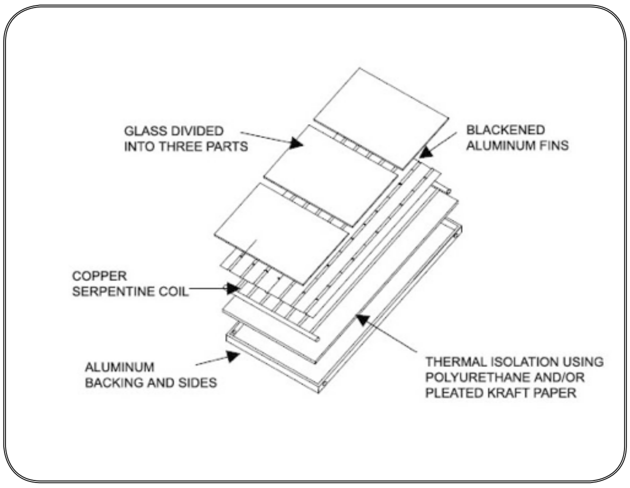


Figure 4 – Detail of the solar panel

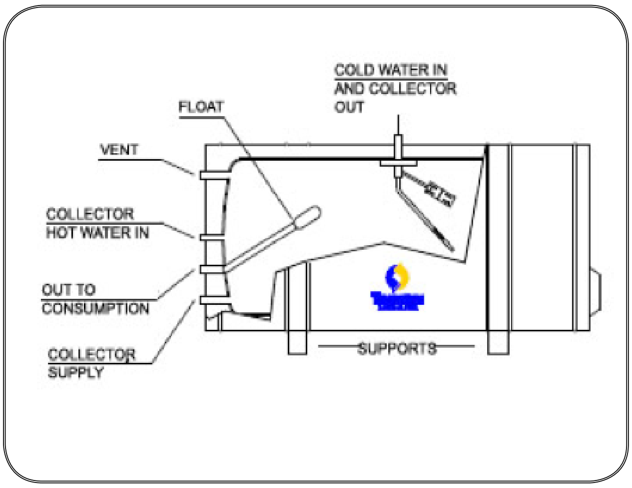
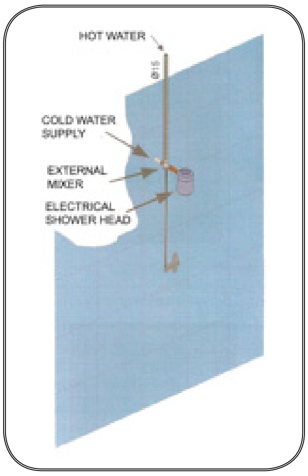


Figure 5 – Detail of the reservoir

Figure 6 – Reservoir set in the roof ridge.



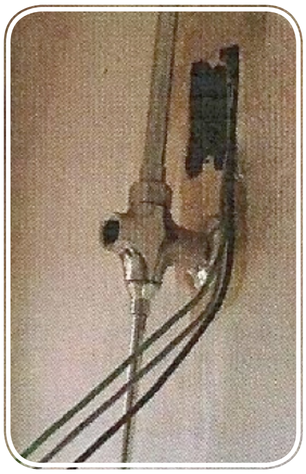


Figure 7 – Detail of the mixer installed on the wall.
Figure 8 – Photo of the mixer installed on the external pipes.

This system also required the use of a mixer, installed in the cold water outlet to the shower and intercepted by the hot water pipe that comes down from the reservoir, crossing parallel to the roof slab. Thus, the mixer was installed outside the wall, as shown in Figure 7 and Figure 8.

The results obtained in the Cafelândia development were so significant that CDHU decided to establish the use of solar heaters as standard procedure in its projects. Thus, the company began to require this system in new undertakings, if there are no restrictions, as of 2008, and to change to this system in houses that have already been built.

This system was first installed in new vertical residential buildings in the city of Mogi Mirim[8], where 433 four-story buildings received solar heating systems in 2010, in the Mogi Mirim E-F-G-H developments.

In Mogi Mirim, the pilot project was implemented using more modern systems, with a panel and coupled reservoir for each apartment, installed on the roof of the buildings. These systems still use electric shower heads for backup, because the waiting time for hot water is approximately 30 seconds. Nevertheless, after the Cafelândia experience with manual electric showers, automatic showers were installed, to control the temperature (thermostat) and the duration of bathing (timer) without user action.

8 Mogi Mirim is located at the east side of the state of São Paulo and has about 88,300 inhabitants.

The timer is a device that determines, based on prior programming, the moments at which the water heater can switch on its heating source (PETRUCCI, 1998).

This technology can limit the duration of bathing and intervals between showers, besides determining the water temperature. It can be used together with the backup electric resistance or with the hybrid-electric solar system (hybrid shower) and its objective is to reduce energy consumption in water heating systems. Figure 9 shows an example of shower timer.

Figure 9 – Shower timer. Source: EWG (2010)

According to the manufacturers, the automatic hybrid-electric solar system can control fluids, pressure and flows through software coupled to the shower. The system is comprised of automation, flow and temperature sensors, a potentiometer and the electric shower.

The system identifies the water temperature, considers the water flows that has been pre-heated by the solar heating system and sends the information to the software, which modulates the shower resistance providing comfort during bath, all independent of user control. In the pilot project, this type of system was used for each apartment, allowing to give more precise information of the relationship between flows and temperature, thus generating greater water and energy savings. The software was installed close to the shower, but could be installed elsewhere, and allowed measuring and verification of consumption data output.

Moreover, the system allows the use of Smart Grid, a device that allows the flow in peak periods to be modulated in order to obtain a suitable temperature, but varying the flow or even shower duration time and also the interval between showers. This system can be installed as long as the user agrees. Another aspects of the system is the installation of a potentiometer that allows the system to be turned off on occasions such as cleaning of the bathroom, which is usually done with the secondary hose attached to the shower, according to information gathered from the users by the manufacturers.

Nowadays, the solar-electric hybrid shower is used in all solar heating water systems in CDHU horizontal housing developments. Moreover, this technology has been used to reduce water wastage in vertical housing developments with 5 and 7 floors.

c) Results

CDHU hired the Institute of Technological Research (IPT) to monitor the results of the implementation of solar systems in the Cafelândia development. The institute carried out four surveys, in April and November 2005, November 2006 and October 2007.

These results showed that, initially, the electricity bill decreased drastically. However, as time went by, it began to increase, but still remained lower than before the use of the solar heating system. Nevertheless, the survey did not find out the reason for the increase in consumption. One of the hypotheses that arose to explain this fact was that the decrease in the electricity bill encouraged people to buy more electrical appliances, thus increasing their electricity bill again. Another possibility is the greater bathing comfort provided by the solar system, which would lead to longer shower times and longer use of the electric backup system on days of little sunshine.

The best results, however, were obtained in user satisfaction. After using the solar heating system, users declared they would even be ready to pay a little higher installment to acquire the system. The main reason for agreeing to the installation of the system was the reduction of the electricity bill.

In vertical housing developments, solar systems were installed in existing developments, as well as in new ones. The first experience was in Mogi Mirim, and the results are being gathered by the local concessionaire Bandeirantes, which financed the implementation of these systems.

In the existing vertical housing developments, the results were not so positive, since there were problems with the supply of hot water to the lower floors and also in the individualized water metering. Therefore, in vertical developments where there is natural gas supply, CDHU is going to install gas water heaters instead of solar ones.

The use of the hybrid-electric solar system has the benefit of reducing water wastage while the user waits for the hot water. Furthermore, it also reduces electricity consumption when compared to the use of a resistance in a reservoir, as a backup system, since it is only used in those moments where a greater volume of hot water is required, as opposed to the resistance, which is automatically turned on when the water temperature decreases below a programmed level.

It was, however, observed that in the first housing development tested, in Cafelândia, some users did not turn off the electric shower when the hot water from the solar heater arrived in the shower, increasing the energy consumption of the household. To solve this problem, CDHU started to use, as a backup system, electric shower heads with automatic switching.

The objective of CDHU was to install 30 thousand solar heaters in its housing developments by the end of 2010, but this number was not counted yet. By 2009, over 15 thousand housing units had already received solar heating systems from CDHU. One of the requirements of the company in public tenders is to use copper tubing. The constructor is responsible for the executive project and for hiring the company to install the system, even though the project must be approved by the CDHU technical staff.

One of the negative results of the system implementation was the increase in water consumption, both from longer bathing time and from cold water wastage while waiting for the hot water, which can be resolved by the use of hybrid showers, reducing this waiting time.

Another negative point is that although the solar heating system works well in one or two-story houses, there are still technical and financial obstacles in higher buildings, particularly with regard to individual hot water metering.

d) Challenges

Among the challenges faced by this technology are:

- Greater detailing of the building plumbing system design for using solar heaters, with analysis of the ideal waiting time for hot water arrival;
- Use of individual hot water metering together with solar heating in multi-family housing;
- Verification of the ideal tilt angle of the panels, which is currently defined by theoretical worksheets or by the manufacturer;
- Obligatory use of antifreeze substances by companies that compete for system implementation in the places in need, due to the occurrence of this phenomenon in some cities of the São Paulo state;
- Incorporation of the maintenance cost for CDHU management for a specific time;
- Since the user needs to maintain the system, training work should be regularly carried out to educate the user in operating and maintaining the system, as well as to promote the sound use of water and energy;
- Elaboration of the study of backup systems for solar heating;
- Revision of the hot water standard ABNT NBR 15569 (2008) and expansion of the QUALISOL and QUALINSTAL programs;
- Replication of initiatives such as the expansion of training centers for installers, based on already consolidated experiences (of ABRAVA or SENAI, as well as Sol Brasil in Belo Horizonte);
- More building alternatives are required for low cost solutions with good efficiency for the social housing sector;
- Evaluation of alternatives in terms of cost-benefit and the system efficiency in terms of the achieved solar fraction and the amount of energy saved;
- Installment of recirculation systems in buildings for the lower floors to avoid difference in temperature between the higher and lower floors, and evaluate the need for thermal isolation of pipes;
- Improved study on the various kinds of devices used as backup for the solar heating system as a function of their cost-benefit;
- Control of the solar-electric hybrid system, whether automatic or otherwise;
- Development of the practice of monitoring the devices´ performance and their use, in order to identify the behavior changes, gains and possible losses of the initiative.

Finally, according to Souza; Abreu (2009), to ensure the success of an incentive program for solar heating systems, continuous monitoring must be in force to confirm if objectives are being achieved. This must be done by establishing measurement and verification plans, the results of which must be proven by strong scientific and technological basis.

1.2.1.2 Gas Water Heating

a) System definition

A gas heating system for water is basically made up of a device for heating the water and a network of pipes that distribute the heated water to points-of-use.

In the case of CDHU, the gas heating system should have an instantaneous water heater and chimney (individual or collective), which should supply hot water only to shower heads in the housing units. Figure 10 shows an example of an instantaneous gas water heater.

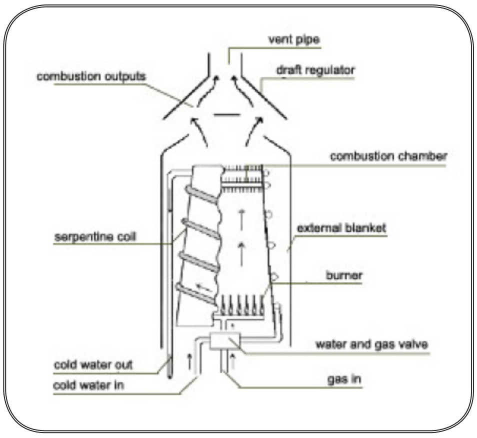


Figure 10 – Example of a tankless gas water heater. Source: Ilha et al. (1994).

b) History of implementation

The gas water heating system is one of the options used by CDHU. LPG cylinders with individual meters were first used in a housing development with 64 apartments in the Jardim São Luiz-A, in Campo Limpo, state of São Paulo, more than 10 years ago. However, the pilot study ran for a specific amount of time and both heaters and metering system were removed after the trial period, and electric shower heads were used again.

Other initiatives took place in some buildings of the metropolitan region of São Paulo, under a contract with COMGÁS, the company responsible for natural gas distribution in the state of São Paulo, who donated the equipment.

In places where a natural gas supply system already exists, attempts are made to use it to heat water with individual gas heaters located in each apartment. In projects with taller buildings (more than 5 stories) gas heating is also indicated because of the difficulties found in the use of solar heating in these cases.

In places in the city of São Paulo without public natural gas supply system, the future use of gas should also be considered.

c) Results

Although these pilot projects were well accepted by users, no studies were carried out to verify whether there had been improvements in the energy and/or environmental performance of these houses. To complement its analysis, COMGÁS is carrying out an R&D project (2010-2011) to verify the impact of the use of gas heaters in multi-family buildings in order to evaluate:

- Feasibility of the use of gas heating integrated to the concept of individual gas metering in the common lobby of buildings;
- Economically viable technological solutions, with high productivity in execution and maintenance;
- Impact on reduction of electricity consumption of the units;
- Analysis of the comfort generated to the final user for bathing;
- Impact on water consumption;
- Final cost of implementation including design, execution and maintenance;
- Structuring of a capacity building and awareness raising program for users on the sound use of resources for sustainability.

d) Challenges

The main challenge of this action is to become competitive in terms of implementation and operation costs, since it requires a more complex system than the hybrid solar system, as for example, it requires inbuilt plumbing.

Furthermore, the concessionaire must guarantee equivalent prices for natural gas and LPG as well as continuous supply of gas to users.

Other challenges include overcoming technical hurdles in using natural gas in multi-family buildings. According to an interview given by Alberto Fossa to Guilherme Conte in the magazine Construção e Mercado 88 (November 2008), despite the challenge of individual metering, gas heating systems should be seen as a backup for solar heating systems in multi-family buildings, since they would permit individual gas metering using a single reservoir in the building with integrated automatic control.

2.1.2 Provision of efficient equipment and electrical appliances

a) System definition

This strategy consists of supplying equipment and electrical appliances with proven energy efficiency to the residents of the CDHU housing developments. In the case of Brazil, the efficiency can be proven through the Brazilian Energy Program (PBE) and the PROCEL and CONPET seals. The Brazilian Energy Program classifies equipment according to their consumption going from A (most efficient) to E (least efficient). The PROCEL seal, on the other hand, aims at showing which electrical appliance has achieved the best efficiency levels within the A category.

Another aim of the seal is to encourage manufacture and commercialization of more efficient products (PROCEL, 2005). The CONPET seal has the same function as the PROCEL seal, but for gas equipment. CONPET also classifies equipment from A (most efficient) to E (least efficient) according to its performance, granting the CONPET seal to the most efficient equipment in the A category.

Figure 11 shows the National Energy Conservation Label of the Brazilian Energy Program, mandatory for some of the household appliances that consume electricity sold in Brazil, and the PROCEL seal and Figure 12 shows the National Energy Conservation Label of the Brazilian Labeling Program, mandatory for some household appliances that consume gas and are sold in Brazil, and the CONPET seal.

b) History of implementation

The first project of this kind was implemented in the housing developments of the Baixada Santista[9], funded by CPFL Energia, the electric energy transmission company that supplies that region. The objective of this project was to replace 40,000 incandescent bulbs by energy saving bulbs.

Afterwards, a project was implemented to replace older refrigerators by more efficient models in housing developments in the metropolitan region of São Paulo. This project was developed with funds from AES Eletropaulo, another electric energy transmission company. Both the new light bulbs and refrigerators were offered directly to the users of the housing developments, without prior consultation on whether they were interested in the replacement.

c) Results

According to CATE (Center for the Application of Efficient Technologies), an initiative supported by AES Eletropaulo and PROCEL, the use of a refrigerator with a PROCEL seal results in energy savings of up to 31% when compared with a common refrigerator; and the use of compact light bulbs with the PROCEL seal results in energy savings of up to 75% when compared to common light bulbs. Also according to CATE, the annual sales of refrigerators with a PROCEL seal have resulted in an energy gain of 667 GWh/year for Brazil.

Figure 11 - Brazilian Energy Program Label for category A and PROCEL seal for appliances that consume electricity

Figure 12 - Brazilian Energy Program Label for category A and CONPET seal for appliances that consume gas

9 Baixada Santista is a region constituted by 9 municipalities including the city of Santos and the south coast of the state. The region has a population of approximately 1.5 million.

In case of refrigerators offered by the CDHU, the appliances were unpacked to reduce their volume, permitting transportation of more units per shipment and consequently reducing transport costs for each appliance. However, upon receiving products without packaging, some users did not accept them, believing them to be used or inferior quality products. Other users did not accept this offer, alleging that the new refrigerators had a smaller volume than their current ones.

With regard to the replacement of the light bulbs, some users sold their new light bulbs when they realized that these had a high market value and then acquired incandescent light bulbs again.

One of the reasons for failure of this action was the lack of an awareness-raising action to inform users of the advantages in replacing the equipment and also to survey their habits to correctly assess their needs.

d) Challenges

The use of efficient equipment by CDHU, such as refrigerators, ventilators and other household appliances with the PROCEL seal and energy saving light bulbs, greatly contributes to reducing the energy consumption of each housing unit.

In the case of refrigerators, an additional criterion for substitution could be appliances that do not use ozone depleting gases, in addition to having high energy efficiency.

Appliances that consume gas with the CONPET seal could also be considered for the housing units, as well as other efficient appliances, such as ventilators.

However, this appliance replacement must always be done together with surveys that show the true needs of users with respect to the appliances, in addition to post-occupation work, to raise the awareness of the user as to the operation and benefits brought by more efficient appliances, thus avoiding their non-acceptance or resale.

Finally, it must be stressed that it is always necessary to carry out a pilot project before any initiative, in order to verify user acceptance.

2.1.3 Photovoltaic energy

a) System definition

Through the photovoltaic effect, the energy contained in sunlight can be directly converted to electricity. The photovoltaic effect is obtained through very thin sheets of semiconductors, such as silicon. When the sun rays reach the surface of the photovoltaic panel connected to an electrical device, an electric current is generated which makes the equipment work.

Panels can be integrated to the project in many ways, they can be installed independently of the building structure or completely fixed to the structure, as a building skin, or even as parts of other elements such as roofs and windows. Furthermore, the energy generated can be stored in batteries or connected to the transmission grid. Figure 13 shows examples of photovoltaic panels in Santa Rosa, California, USA, and Figure 14 shows a diagram of photovoltaic solar panels in a household, connected to the transmission grid.

In addition to energy savings, Photovoltaic systems can provide electricity in places distant from the transmission grid or simply be used in co-generation to reduce the costs of energy supplied by the utility companies.

Figure 13 – Photovoltaic panels in Santa Rosa, California, USA. Source: http: //www. aondevamos.eng.br/textos/galeria02.htm

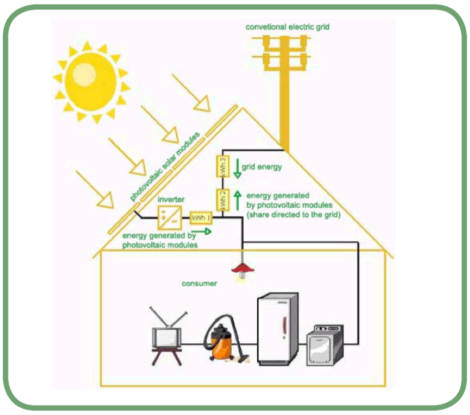


Figure 14 - Scheme of an installation of photovoltaic solar panels in a household

The main components of these systems are:

- Panels or modules of photovoltaic cells;
- Supports for the panels;
- Battery charge controller (it can be removed in the case of co-generation);
- Battery bank;
- Current inverter (converts direct current from batteries to alternating current).

Figure 15 shows a scheme of the photovoltaic energy system operation and its components.

b) History of implementation

The system was first implemented in 2002, in 5 indigenous dwellings in the village of Terra Indígena Guarani do Ribeirão Silveira, in Boracéia, municipality of São Sebastião[10], with resources from Companhia Eletrobrás/Furnas[11]. The photovoltaic system was deactivated in mid-2010, with the arrival of the transmission grid at the village.

Recently (in September 2010), photovoltaic systems were implemented to light a public area (plaza) in the housing development of Rubens Lara, within the Program to Recover the Serra do Mar, in Cubatão[12], with expected monitoring.

c) Results

In the first settlement implementation, in Boracéia, the cost for implementing this technology was very high and CDHU initially set this program aside. However, in terms of energy savings, the program results were satisfactory and, thus, these systems will be used once again in other housing developments.

d) Challenges

The main challenge of this action is to achieve a competitive price in comparison to other technologies for reduction of energy consumption. Furthermore, better evaluation of benefits should be carried out for use in common areas in comparison to use in private areas.

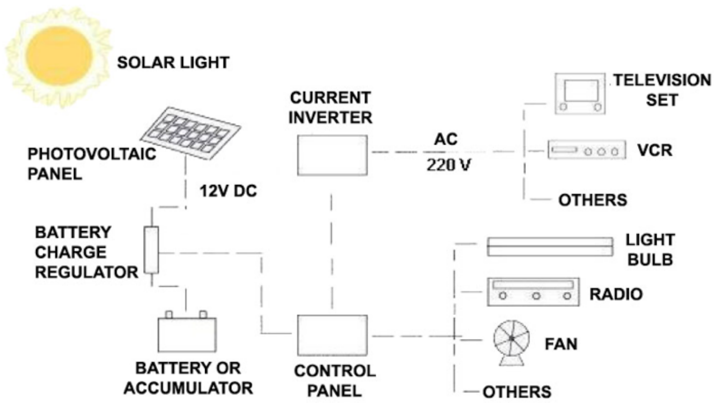


Figure 15 - Photovoltaic energy system. Source: SOLARTERRA (2010)

10 São Sebastião is a municipality located on the north coast of the state of São Paulo with about 73,600 inhabitants. Boracéia is a beach that belongs to São Sebastião.

11 Company that deals with generation, transmission and commercialization of electricity in some Brazilian states (covering 51% of Brazilian homes).

12 Municipality that belongs to Baixada Santista, as mentioned before, but it is not a coastal city.

2.1.4 Standardization of ceiling height

a) System definition

The dimension of the ceiling height is an architectural property that directly influences the thermal comfort. Since hot air rises to the upper part of an environment and cooler air remains in the lower part, areas that have a greater ceiling height can better separate the user from the hot air mass. However, to achieve the desired result, this must be combined with other architectural elements that improve the internal air circulation and insulate the environment, in addition to providing appropriate solar orientation in the design phase.

b) History of implementation

In CDHU, house typologies used to have a height of 2.60 m, the minimum height permitted by the Código de Obras e Edificações in most Brazilian cities. However, during the nineties, two typologies for 5-story buildings that had a ceiling height of 2.40 m were used. This minimum height was allowed by the legislation of certain municipalities, such as Campinas , and aimed to adapt the five floors to the maximum permitted height for buildings in these municipalities in these two typologies. This height was discarded in CDHU projects, who uses a height of 2.60m for both houses and buildings.

c) Results

When placing the user in an area with a lower temperature, substantial improvement is obtained in his thermal comfort, particularly in tropical regions, where sunshine is more intense and temperatures higher. It is possible to reduce the need for air conditioners or mechanical ventilation, leading to a reduction in energy consumption in these buildings. In addition, taller ceilings provide better visual perception to the user inside the building.

However, using higher ceilings implies less population density, if the building is kept at the same height, and consequently, increase in cost per m² of construction, since the cost of construction is "diluted" in fewer units.

d) Challenges

Raising ceiling height can be more effective for the thermal comfort of users if associated to other actions such as innovation in window frames, although this may increase building costs, requiring a more extensive cost-benefit analysis. The hot air accumulated in the upper areas of the environment must be removed to improve the thermal comfort in summer. This can be thought of in terms of innovation in window frames, where in larger environments there could be openings at the top, sheds or similar alternatives. The increase in the ceiling height can also have a positive influence in increasing natural lighting, insofar as it provides the possibility of taller windows or French doors, achieving greater natural lighting inside the house.

2.1.5 Use of roof lining

a) System definition

According to Lamberts; Triana (2005), the use of roof lining is necessary to ensure a minimum thermal performance and should be a basic and minimum requirement for project approval in the social housing sector, since it is an important component of public policies for energy performance of buildings.

Moreover, the authors say that, although it is included in the minimum specifications for social housing, this does not correspond to current reality and when it is required, it is only installed in places like kitchen and bathroom, and usually wood or PVC is used to line the roof.

The use of a roof lining creates a thermal isolating layer that separates the environment occupied by the user from the heat radiated through the roof during the day and reduces heat losses during the night, so as to increase the thermal resistance of the house covering. The lining can be made of plaster, wood or PVC, among others. A roofing slab can also be used, which consists in applying a layer of reinforced concrete; it can be a mixed slab with bricks, EPS or concrete slab. CDHU usually uses mixed slab lining in its projects.

The ABNT NBR 15575 (2008) standard recommends the use of coverings with thermal transmittance (U) in accordance with the solar radiation absorbance (α) of the roof (as a rule, darker colors have a greater absorbance than lighter colors).

For bioclimatic zones 3 to 5 (ABNT NBR 15220-3), where most of the CDHU projects are situated, the standard recommends the following: $U < 2.30$ if $\alpha < 0.6$ or $U < 1.5$ if $\alpha > 0.6$.

The tables below show the thermal transmittance (U) of different kinds of covering: with clay roofing tiles and mixed slab (Table 3); with clay roofing tiles and wood lining (Table 4) and with clay roofing tiles, wood lining and insulating aluminum foil laminate (Table 5) with clay roofing tiles and slab lining with EPS (Table 6). Table 7 shows the transmittance and thermal capacity of roof slabs without tiles, precast in clay and precast with EPS filling.

Tables 3 and 4 show that the thermal transmittance does not vary significantly when clay roofing tiles are used with either a mixed slab or wood lining. Therefore the use of mixed slab lining does not translate into significant improvements in the thermal performance of the building, since because of its greater thermal capacity it accumulates heat during the day returning it at night, which, during times of the year like summer, would not be desirable.

But when clay roofing tiles are used with a wood lining and a thermal insulator, the thermal transmittance of the covering lowers significantly, as seen in Table 4, remaining with low thermal capacity. This happens because of the low conductivity of the thermal insulating material.

In Table 5, we notice the values for clay roofing tiles when used with a slab lining with PS. In this case, the transmittance and thermal capacity decrease a little in comparison to Table 2. Table 6 shows the transmittance and thermal capacity of the precast slabs with bricks and EPS. Therefore, when using slab as a lining, depending on the conditions, it could be better to use slab with EPS, since its transmittance is a little lower than the mixed slab.

Covering	**Description**	**U [W/m².K]**	**TC[kJ/(m².K)}**

Table 3 – Transmittance [U] and thermal capacity [TC] of clay tile covering and mixed slab lining. Source: NBR 15220-3 (ABNT, 2005)

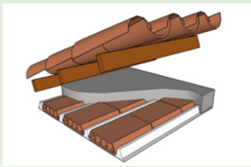
	Clay roofing tiles covering with air gap and mixed slab lining Thickness of the tile: 1.0 cm Thickness of the slab: 12.0 cm	1,79	185

Table 4 – Transmittance [U] and thermal capacity [TC] of clay tile covering and wood lining. Source: NBR 15220-3 (ABNT, 2005)

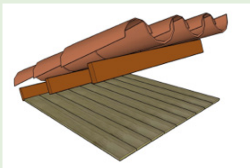
	Clay tiles covering with air gap and wood lining Thickness of the tile: 1.0 cm Thickness of the slab: 1.0 cm	2,02	26,4

Table 5 – Transmittance [U] and thermal capacity [TC] of clay tile covering, aluminum sheet and wood lining. Source: NBR 15220-3 (ABNT, 2005)

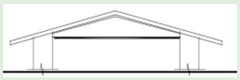
Covering	**Description**	**U [W/(m².K)]**	**C_T [kJ/(m².K)]**	**□ [hours]**
	Clay roofing tile covering, polished aluminum sheet and wood lining Tile thickness: 1.0 cm Wood thickness: 1.0 cm	1,11	32	2,0

Table 6 – Transmittance and thermal capacity of clay roofing tiles and slab lining with PS. Source: Selo Casa Azul da Caixa (JOHN et al., 2010)

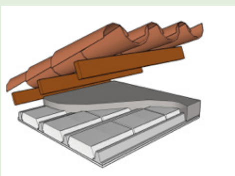
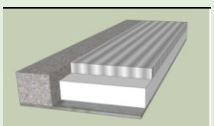
	Clay tile covering with air gap and slab lining with PS Thickness of the tile: 1.0 cm Thickness of the slab: 12.0 cm Rt (slab) = 0.44 (m2. K/W) TC(slab) = 263 kJ/(m2.K)	1,52	150

Table 7 – Transmittance [U] and thermal capacity [TC] of precast slab with bricks and precast slap with PS, both without tiles. Source: Selo Casa Azul da Caixa (JOHN et al., 2010)

	Precast slab with bricks (12.0 cm) No tiles	2.95	167
	Precast slab with PS and no tiles (12.0 cm) Thickness of concrete: 4.0 cm Thickness of PS: 7.0 cm Thickness of plaster: 1.0 cm	2.29	132

b) History of implementation

Previously, single family units were only covered with roofing tiles, without slab lining. That, however, is being changed to improve the quality of the houses, the thermal comfort of users and the aesthetic aspect of the dwelling. Starting in 2007, CDHU began to use slab lining in its housing projects and, currently, all the typologies are delivered with slab lining.

c) Results

The main benefit of this action is greater thermal comfort for residents, when compared to the use of roofs without any kind of lining (Table 8). Furthermore, the use of slab or lining creates a cozier and more pleasant environment for residents, hiding components such as tiles, wiring and plumbing, providing a greater bond of the residents with their houses.

However, the use of these components increases the cost of the housing unit, since it requires more finishing materials and additional labor, a very relevant factor when dealing with the construction of social housing.

d) Challenges

The main challenge of this action is to use materials that provide good quality to the house but at a reduced cost.

Table 8 – Covering with a transmittance [U] of 4.55 [W/(m2.K)], Thermal Capacity [TC] of 18 [kJ/(m2.K)] and Thermal Delay [□] of 0.3 hours. Source: NBR 15220-3 (ABNT, 2005)

2.1.6 Use of metal structure and tiles for roofs

a) System definition

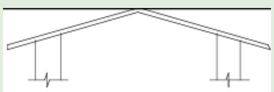
This action defines the use of steel roof structures, replacing the wooden structure, and metal roofing tiles painted white to replace the clay tiles.

According to Bueno (1994) and Lamberts (1983), the permeable clay tile has a better thermal performance than the waterproof ones, because its porous structure is more suitable for adsorption and desorption of humidity with significant heat exchanges. This property allows the temperature to rise at night, having a higher nocturnal temperature than the others; during the day, it has a lower temperature because of the process of evaporating the humidity incorporated over the previous night.

The figures below show the characteristics of transmittance (U) and thermal capacity (TC) for clay tile coverings and metal tiles with mixed slab lining and slab lining with PS. In addition to a simplified calculation of the heat flow for horizontal surfaces[16] as an example, the incident solar radiation for a horizontal surface on the 22nd of December at latitude 30ºS at midday and considering that the house is very well ventilated, internal and external temperatures were taken to be the same. This is to show the relationship between absorbance and transmittance of the various kinds of covers.

As to the transmittance, clay tiles and metal tiles have very similar behaviors, depending far more on the use of components such as lining, insulation or air gaps in the covering (Tables 9 to 11). In the case of heat flows, Tables 10 and 11 show that the most important characteristic is the absorbance of the material (generally associated to the color). That is the reason for specifying the use of light colors for coverings or of materials with a low absorbance.

Table 8 – Covering

Covering	Description	U [W/m².K]	TC[kJ/(m².K)}	□ [horas]
	Clay roofing tile covering with no lining Tile thickness: 1.0 cm	4,55	18	0,3

16 Using the formula: □ = U*A (TEXT + α*SR*Res – 4 – TINT). For the example, incident solar radiation (SR) for a horizontal surface of 1134 W/m² was used for the 22nd of December at the latitude 30ºS. The TEXT (external temperature) and TINT (internal temperature) are taken to be the same for a very well ventilated house. The Res (external surface resistance) adopted is 0.04 m²K/W, for a downward heat flow.

However these simplified mathematical calculations cannot show the gain from evaporation that a natural clay tile has, which, according to Lamberts (1983) leads to a reduction of around 20% in the heat flow, considering a normal day without rain. This value may be greater on rainy days.

Thus, the choice of covering can be more closely associated to the context, that is, climate, availability of materials, durability and also to the required acoustic treatment, which must be considered with metal tiles.

Covering	Description	U [W/m².K]	TC[kJ/(m².K)]

Table 9 – Comparison of transmittance [U] and thermal capacity [TC] of clay and metal tile coverings (both without lining). (NBR 15220-3, 2005)

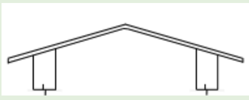
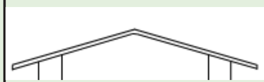
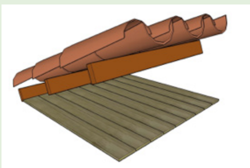
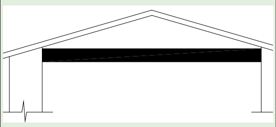
	Metal tile covering without lining Thickness of the tile: 0.65 mm	4,76	2,33
	Metal tile covering without lining Thickness of the tile: 1.0 cm	4,55	18

Table 10 – Comparison of transmittance [U] and thermal capacity [TC] of clay and metal tile coverings (both with mixed slab lining). Source: Based on NBR 15220-3 (ABNT, 2005)

	Clay tiles covering with air gap and mixed slab lining Thickness of the tile: 1.0 cm Thickness of slab: 12.0 cm (4 cm of concrete + 7 cm clay bricks + 1 cm of plaster) Heat flow: Light colored tile (α =0.3) = 17.29 W/m2 Natural colored tile (α =0.75) = 54 W/m2	2,02	26,4
	Metal tiles covering with air gap and mixed slab lining Thickness of the tile: 0.65 mm Thickness of slab: 12.0 cm (4 cm of concrete + 7 cm clay bricks + 1 cm of plaster) Heat flow: Light colored tile (α =0.3) = 17.48 W/m2 Natural colored tile (α =0.75) = 54.93 W/m2	1,82	16,9

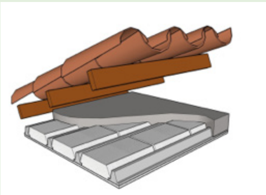
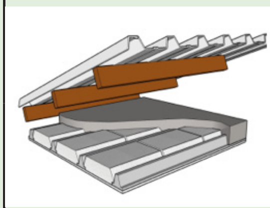
Covering	Description	U [W/m².K]	TC[kJ/(m².K)]
	Clay tiles covering with air gap and slab lining with EPS Thickness of the tile: 0.65 mm Thickness of slab: 12.0 cm (4 cm of concrete + 7 cm clay bricks + 1 cm of plaster) Heat flow: Light colored tile (α =0.3) = 14.60 W/ m2 Natural colored tile (α =0.75) = 45.63 W/ m2	1.52	150
	Metal tiles covering with air gap and slab lining with EPS Thickness of the tile: 0.65 mm Thickness of slab: 12.0 cm (4 cm of concrete + 7 cm clay bricks + 1 cm of plaster) Heat flow: Light colored tile (α =0.3) = 14.79 W/ m2 Natural colored tile (α =0.75) = 46.23 W/ m2	1.54	142

Table 11 – Comparison of transmittance [U] and thermal capacity [TC] of clay and metal tile coverings (both with slab lining with EPS). Source: Based on NBR 15220-3 (ABNT, 2005)

b) History of implementation

The standard material used by CDHU for the structure of the roofs of the single and multi-family buildings was wood. Alternative solutions, such as a steel structure, were also adopted, but, given the wide variation in market prices, in the long run it may prove not to be a feasible option.

On the other hand, one of the concerns with wooden structures is their quality, given that low-quality wood can lead to structural problems in house roofs. In order to be able to keep using wood, CDHU adopts acquisition procedures that seek to ensure that the wood has certified quality.

However, in a scenario of growing concern with the ability to prove the origin of the wood (state Decree No. 53,047, dated June 2nd, 2008) and with the dissemination of the use of steel in the production chain in civil construction, CDHU started to use steel more often in its roofing structures. This is seen more clearly in the projects for single story houses that currently almost always use steel structures.

The use of steel in roof structures began with COSIPA (Steel Company of São Paulo) supplying steel as payment for a debt it had with the state of São Paulo.

In the Serra do Mar project, the houses in the Rubens Lara development will use steel roof structures.

As to the use of tiles, the tiles used in CDHU vertical housing developments are made from fiber cement or metal, because of their lower cost. However, due to the absence of platbands to protect the cover of the enclosure, many tiles were removed. To resolve this problem, CDHU adopted, starting in the eighties, the use of clay tiles in buildings, which were already being used in one-story houses.

However, from 2007, CDHU began to use slabs on the roof of its buildings, which eliminated the problem with tile removal and allowed the use of a smaller slope for the roof, and, thus, metal and fiber roofing tiles. Since then, CDHU has adopted the use of this type of tile, painted in white, to improve the thermal comfort of users.

c) Results

The use of clay roofing tiles represents an increase in the thermal comfort of houses and user, in comparison to some covering systems. However, the use of this tile implies in lower labor productivity, in comparison with fiber cement or metal coverings, and, therefore, greater costs with its installation. Moreover, clay tiles increase the cost of installation and maintenance of the roof structure.

In roofs with steel structures, the disadvantage is the initial higher cost, and possible problems in the sealing, if joints are soldered instead of screwed together.

d) Challenges

The main challenges of this action are to verify the ideal conditions for the use of metal tiles painted white, fiber cement tiles or clay tiles depending on the context and to prove if it is more sustainable to use the steel structure rather than certified timber.

2.1.7 Remote metering of energy inputs

Telemetry refers to the automation of measurements and their transmission, from the source to a processing center (DOMINIQUELI, 2007). This technology has been adopted for remote metering of the building inputs, without the need for persons to come to the building to take readings.

According to Paulino (2006), automation of the measuring and reading process, using existing meters or electronic meters has several advantages, which include: combating frauds, implementation of differentiated tariffs based on the time consumption, remote cut off and restoring of supply, determining load curves and eliminating error and costs associated with manual reading.

In addition, remote metering dispenses the need for gas and electricity measurement centers, allowing better use of these areas (CDHU, 2005).

Remote metering technologies for buildings available in the market are: radio frequency, PLC, telephone networks (landlines and mobile), cable TV, satellite, field bus and hybrid systems (ROZAS, 2002). CDHU initiatives for remote metering are presented below.

2.1.7.1 Power Line Communication (PLC)

a) System definition

Power Line Communication (PLC) is a technology for communicating through the electricity grid. It is possible to use this technology to transmit information about individual electricity, gas and water metering, as well as to provide internet and cable TV services (for digital inclusion programs).

The signals normally used for communication through metal environments undergo a lot of electromagnetic interference in branched networks full of devices such as capacitors and transformers. However, when operating at communications frequencies of several hundred Hertz, it is possible to transmit a small amount of data, enough for the meter readings, making it one of the most used systems all over the world (DOMINIQUELI, 2007). Figure 16 shows an example of a metering system using PLC.

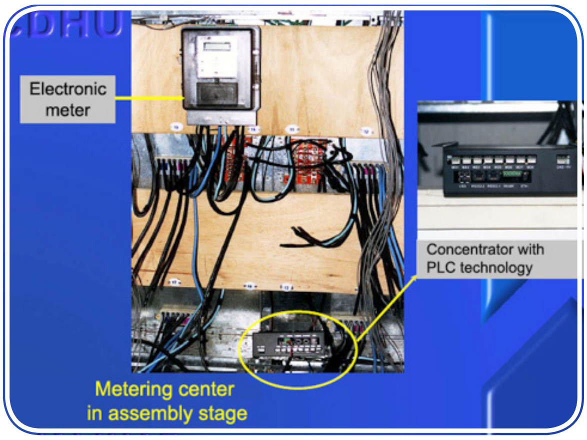


Figure 16 - Detail of the metering concentrator and electronic meter with PLC. Source: CDHU (2005)

b) History of implementation

This technology was first used in a pilot project in the housing development in the neighborhood of Mooca, in the city of São Paulo, in 2003.

The technology was used to measure individual consumption of water, electricity and gas of each housing unit of the development, in addition to connecting the computers for common use by residents, through the adoption of a room previously used for the traditional water, electricity and gas meters.

The electricity company responsible for the technology implementation used the pilot project to evaluate remote metering and distance reading. However, during this pilot project, there was no effective use of the metering for individual bills by the water company or by the building administration.

Figure 17 illustrates how the individual metering with PLC technology worked and Figure 18 shows some of the components installed in one building of the housing development of Mooca.

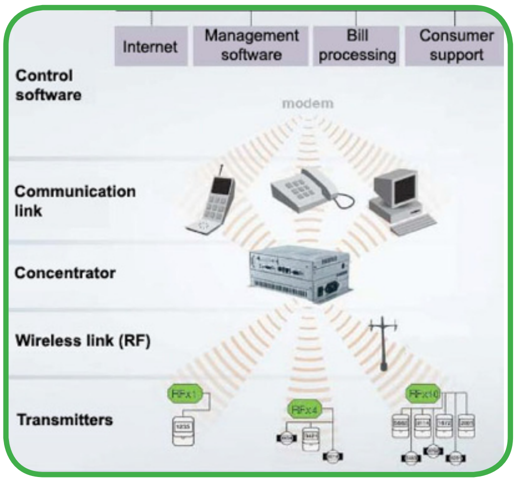


Figure 17 - Diagram of the macro operation of the Mobix S.A. PLC system. Source: Mobix S.A. (2010)

Figure 18 - Individual metering system with PLC technology in the CDHU's Mooca development.
Source: QUALIHAB (2005)

c) Results

The use of PLC is considered to be very good by CDHU technical staff since it uses existing infrastructure and does not need new installations. Furthermore, it does not require additional communications infrastructure such as cabling or transmission antennas, since data transmission is carried out through the existing electricity grid, only measurement equipment is needed.

Another positive point is that, when the user does not pay his bills, it is possible to cut off water and electricity and later restore them remotely. But, in the case of gas, it is only possible to cut off remotely, restoring of the service has to be done manually by a technician, to avoid eventual accidents.

There were, however, technical problems in the use of this technology due to the absence of UPS and enough memory to store all the data.

Furthermore, all the water, electricity and gas data were collected by the electricity company, Eletropaulo. This led to problems with the other utility concessionaires (SABESP and COMGÁS), who wanted to receive the data directly, without going through Eletropaulo.

Finally, to implement PLC, the initial investment for each building is increased because of the acquisition of meters with PLC technology.

d) Challenges

The main challenge of this action is to resolve the technical problems, with the adoption of technologies that have associated equipment such as UPS and enough memory, and problems related to distribution of data among all the utilities.

2.1.7.2 Electric bus

a) System definition

Electric buses are sets of buses that conduct electricity, usually made off copper, built within an earthed metal enclosure. The buses are supported and insulated from each other and the housing by insulators (FISHMANN; BOMEISEL, 2000).

Using this technology, the cabling of each floor is connected sideways, reducing losses and avoiding voltage drops on the top floor. In addition, the bus does not need individual meters.

b) History of implementation

The solution was implemented in the CDHU's Mooca unit in 2003, together with other solutions such as individual metering and remote metering, both using PLC technology. Below are some illustrations of the systems used in these units.

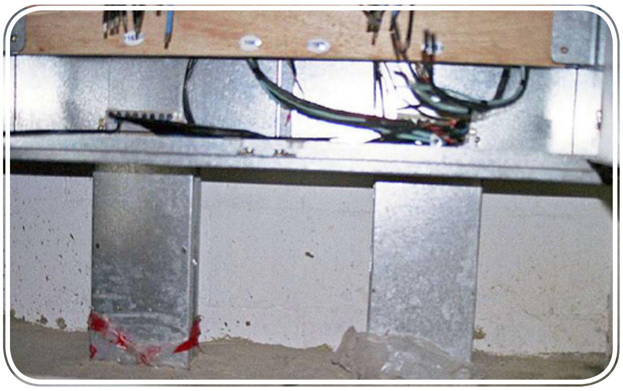


Figure 19 - Detail of the buses that replace the three flexible cables that supply each apartment.
Source: CDHU (2005)

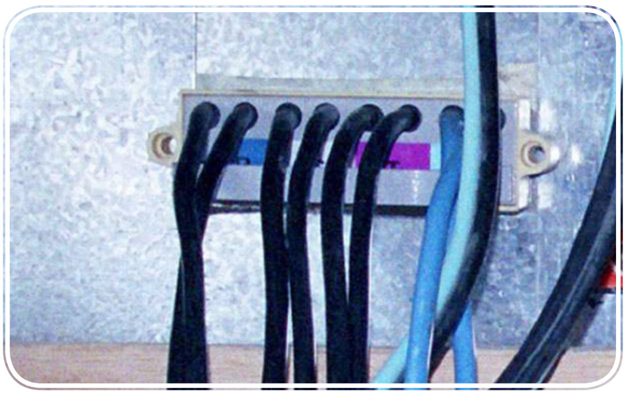


Figure 20 - Plug-in for connection of installed bus. Source: CDHU (2005)

2.1.8 Window frames and shading

a) System definition

According to Lamberts and Triana (2005), windows are the components that most influence the thermal performance of the house and the ones that have undergone the least technological development in all sectors and income ranges in general in Brazil, urgently requiring some innovation. According to the same authors, windows should be able to respond efficiently to the various climate patterns seen in the country, with good sealing in cold climates, and allowing for ventilation and shading/darkening in hot climates. In social housing, the quality of windows directly reflects the target population. The materials most used are steel plates for housing for lower income families and wood and aluminum for populations with somewhat higher purchasing power.

A research carried out by Ino et al. (2003), in the city of São Paulo, identified the types of window most used in housing, and classified them by income and market price. Four classes were considered: Class 1 for aluminum windows, mostly used by the middle class; Class 2 for aluminum windows with 3 sections and for steel plate windows of superior quality, used by the middle class in apartments and houses in housing development and by self-builders; Class 3 for steel plate windows with smaller dimensions and lower quality, used by self-builders and property owners in the outskirts; and Class 4 for lower income ranges and self-builders in the outskirts.

Comparisons using percentages for cost analysis and using the price for the lowest income range (Class 4, BRL 45.67) in the 2003 survey as a baseline would result in:

- Class 4 (baseline price);
- Class 3 (+52% of the baseline price);
- Class 2 (+100% of the baseline price); and
- Class 1 (+240% of the baseline price).

This shows the need for innovation in window frame components to meet the requirements for quality and performance and for prices to remain affordable to all income ranges.

Among the window components, special attention should be given to shutters, since shading of the window represents an important improvement in the thermal performance of the environment, particularly when low absorptance, normally associated to light colors, is considered.

b) History of implementation

Some issues related to the use of window frames by the CDHU are as follows:

1. In buildings windows that open out are not used, because they are more expensive;
2. All windows are sliding, even though they are more expensive but they are very good in providing adequate lighting and ventilation;
3. In bathrooms tilt windows (maxim-ar) are used;
4. The windows are mostly aluminum and some are PVC, although it is more expensive.

c) Results

According to a conversation with an architect Adriana Levinsky, responsible for the Rubens Lara project, located in the Bairro Jardim in Casqueiro, Cubatão, which is part of the Socio-Environmental Recovery of the Serra do Mar Project sponsored by the state government of São Paulo, several innovative actions regarding the window frames were implemented in this project:

- Frames with aluminum molding and electrostatic painting in white and 4 sliding panes in the areas where users stay for a long time, 4 internal glass panes and 4 shutters in bedrooms to allow greater ventilation and lighting. This doubled the area normally used for frames.
- This criterion for frames was used in the multi-family typologies as well as those of blocks of semi-detached and superimposed houses, which are grouped together in lots of 6 houses, i.e. four 2-story semi-attached houses and two 1-story superimposed houses per block.
- The Accessibility Standard NBR 9050 requires that the window sills of the living areas should be changed in new projects to 60 cm, allowing children and wheelchair-bound persons greater visibility of the external area. This allows new designs for the molding, making use of the lower transom or complementing with fixed glass pane.

d) Challenges

Challenges for this action include the need for innovation in window frames, taking into account the windows and shading, either with the use of shutters or other solutions. There is a need for windows that meet the basic requirements with greater flexibility, in order to ensure a better adapted to the climate.

In addition, it is necessary that the projects take into account an increase in the space for ventilation and lighting to obtain more appropriate comfort conditions, according to the requirements for the performance standards in the different climate zones.

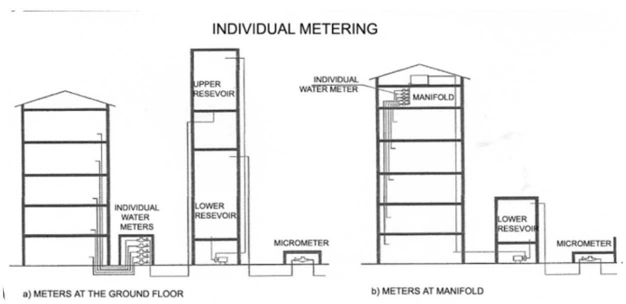
2.2 Sound use of water

2.2.1 Individual water metering

b) System definition

Individual water metering requires the use of a water meter capable of providing the data of water consumption in a single housing unit both in vertical and horizontal condominiums. In that case, the water bill can be prepared for each unit separately, considering the consumption registered by the respective water meter, together with the share of the water consumed for collective purposes of the building (DOMINIQUELI, 2007).

Figure 21 shows examples of individual water metering typologies, with meters installed on the ground floor and a tower-like reservoir and meters installed at the manifolds.
Figure 21 – Examples of vertical buildings with individual water metering. Source: DOMINIQUELI (2007)



For SABESP (Basic Sanitation Company of the State of São Paulo), individual water metering arose out of market demand, encouraged by the sound use of water and particularly by the clients´ need to control their consumption and pay only for the amount actually consumed. Individual metering carried out by SABESP has the advantage that the administration of user defaults might be done by the company itself. It also raises the awareness of the user with respect to use of water, since now he pays exactly for what he consumes.

This model was developed through the creation of a Program for quality and productivity of individual water metering (ProAcqua), whose objective is to increase the levels of quality and productivity of individual water metering systems in buildings, those in use as well as the new ones, to ensure performance and effectiveness of the systems, providing efficiency and reliability for consumers.

When the individual metering service was officially launched, in December 2008, the need to expand the technical knowledge of the professionals involved with the clients, in the area of engineering, customer relations and others was affirmed.

The ProAcqua actions are systemic and include the establishment of mechanisms, technical documents and normative references that ensure: the quality of the professionals involved (project, execution and maintenance of the hydraulic building systems); use of materials in conformity with the Brazilian technical standards (PBQP-H Sectoral Quality Programs) and the evaluation of innovative technologies, guaranteeing the performance of the systems and, thus, protecting the final users, in addition to having the system managed by companies certified by the system.

Furthermore, the environmental education actions of ProAcqua aim at informing the final users about the importance of the quality of the hydraulic systems in their buildings, about the benefits of the individual metering as a tool for water management and about the role of Brazilian society in the issue of the sound use of water.

The technical solution adopted by SABESP involves a reading of two meters – for cold and hot water, and the meters are located in the common area of the housing units. The system includes remote metering of water, as well as possibility to cut off the water remotely. The implementation of the individual metering system is carried out by technology companies certified by ProAcqua, whose technologies are approved and who have one or more technicians responsible for the phases of project design, its execution and system maintenance. Sabesp is responsible for billing and administration of defaults.

In the case of CDHU and other popular housing projects, more discussions are needed on the management of system operation and maintenance, since the impacts caused by the amounts charged for system maintenance present a disadvantage to this solution, as users often cannot afford these monthly expenditures.

c) History of implementation

The first pilot projects were ran in the housing developments located in the neighborhood of Itaim Paulista, in eastern zone of the city of Sao Paulo, with 160 apartments, and in the city of Santos, summing to more than 500 units. At the end of 2005, these pilot projects installed meters on the ground floor and had a tower-like reservoir with pressure box. In this case, reading of the water meters was visual, at the ground floor. Figure 22 shows a CDHU housing development with round tower-like reservoirs.

After this first pilot, individual metering with standard metal cover was used in vertical developments of 5, 6 and 7 stories. Meters could be installed in the manifolds or on the ground floor of the buildings. Another pilot project took place in the Cangaíba housing development, in the eastern zone of the city of Sao Paulo, after the construction of buildings was completed. Before installation of individual metering, each building had one central meter and the water costs were shared between all building residents. Figure 23 shows the internal individual metering in the manifold.

The first type of technology using meters on the ground floor and tower-like reservoir with pressure vessel was rejected, since SABESP did not accept individual metering unless it was done remotely, i.e. without the need to carry out reading of the measurement in the place.

Likewise, the metering technology using water meters in the manifold was not accepted by SABESP because it required a technician to access each floor of the building.

Finally, the remote metering technology was accepted by both SABESP and residents and it is currently used in all CDHU housing developments. Figures 24 and 25 show details of the remote individual metering systems used in the Francisco Morato housing development.

CDHU implements currently individual water metering in all new projects for multi-family buildings and it carries out projects of adaptation to individual metering in existing buildings.

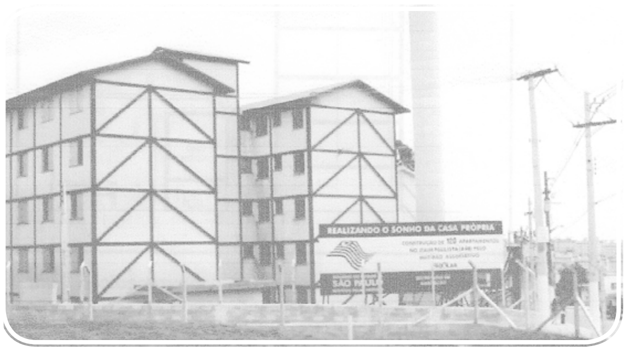


Figure 22 – CDHU buildings in the Itaim Paulista housing development, with individual metering and round tower-like reservoir. Source: QUINTANA NETO; RIZZO (2006) apud DOMINIQUELI (2007).

Figure 23 – Internal measurement in the manifold, accessed by the staircase, in a 6-story building. Source: DOMINIQUELI (2007)

Figure 24 - Remote individual metering system in the Francisco Morato housing development. Source: MOBIX S.A. (2010)

Figure 25 - Remote individual metering system in the Francisco Morato housing development. Source: MOBIX S.A. (2010)

In its public tenders, CDHU requests the use of the ProAcqua model, which details the technical standards of the installations with regard to meters cover, position of water meters (according to NTS-277 and NTS-279, SABESP technical standards regulating criteria for the deployment of individual metering in condominiums and for remote measurement), quality of the materials to be in accordance with Brazilian technical standards, in addition to evaluation of metering technologies by a system of approval and certification of professionals and companies interested in project management, its execution and maintenance of the individual water metering systems.

Water metering units are preferentially installed in the manifold above the staircase, below the upper reservoir or in the landing of the apartments at the top floor, in the common area of the units. In addition, they contain a data concentrator which should be in an accessible position for easy reading by SABESP employee, preferably on the ground floor or in the security booth.

Water consumption measurement should be remote, allowing the metering, reading, cutting off and restoring of water consumption at each metering point, through a control center, without the need for enter the apartment or even the building. The system should allow reading of individual consumption in a data concentrator certified by ProAcqua, meeting the requirements of NTS-279.

This technology will be also used in the Bolsão 7 of the Program to Recover the Serra do Mar, in Cubatão.

c) Results

The users are charged for their own consumption, instead of paying a share of the building consumption. Furthermore, they are not responsible for possible waste generated by other residents. Since the variation in consumption of their own household has a greater impact on their water bill, there is a significant decrease in consumption, particularly as these are housing units for lower income populations. Additionally, there is a feeling that the charge is fair, since the users pay for what they consume.

The introduction of individual water metering was quite satisfactory from CDHU's viewpoint; this led to the adoption of this technology as standard and written into law through a government decree in September 2007. The CDHU Project Manual prescribes that all buildings should have equipment for measuring individual consumption for hot or cold water installations. The revision/installation of the individual metering system does not preclude the obligatory installation of a general meter at the disposal of the local water concessionaire, who will define its standardization. "A remote system for metering/cutting off/restoring should be included according to the specific CDHU guidelines or those of the local concessionaire" (CDHU, 2008).

According to CDHU technicians, during a pilot project in the town of Itapetininga, carried out by SABESP, where this technology was adopted, a reduction of 30% in water consumption was observed, not only due to the user's change in behavior, but also because of better identification of losses in the water installation that this technology provides. Table 12 shows a comparison of consumption before and after individual water metering in the Itapetininga pilot project. The lower reduction in the monthly cost is related to the additional management costs.

Table 12 – Comparison of consumption before and after individual water metering in the Itapetininga pilot project.

Consumption Comparison after Individual Metering 28 families	
Average Monthly Consumption per Apartment	
Before	After
13.6 m3	8.79 m3
Savings of 32.7%	
Average Monthly Cost per Apartment	
Before	After
R$ 28.29	R$ 26.38
Bill reduction of 6.76%	

Before CDHU adopted this technology, in some of the housing developments, the residents themselves requested individual metering services, offered by private companies that were executed with low quality, often not meeting the standards, and compromising the performance of the building's water and structural systems. In some cases, these companies impose management contracts that give them powers that go beyond cutting off the water supply of units in default. They collect condominium charges that are not always transferred to the concessionaire, further harming families (DOMINIQUELI, 2007).

Even with the additional management costs of the system, residents preferred the use of this technology and demanded that CDHU negotiated with the concessionaire about the preference of individual bills (DOMINIQUELI, 2007).

With the implementation of individual metering by CDHU, reading of data is carried out by SABESP, while equipment maintenance is performed by companies accredited by the ProAcqua seal and hired by the condominiums. Those outsourced companies are responsible for system maintenance and operation of the valves that cut off water supply, if the resident defaults and his supply is cut off. Thus, for the correct operation of the entire system, constant maintenance is required and of course this leads to increased maintenance costs.

Since the chosen technology measures the consumption of water before it reaches the heating system, the technical difficulties in measuring hot water have been avoided.

d) Challenges

Among the main challenges of this action are:

1. Reduction in costs from the system maintenance, which would reduce the resident's condominium charge;
2. Implementation of the individual metering in housing developments already in use, in order to prevent the encroachment of the private companies that provide low quality metering services;
3. Use of individual water metering in hot water installations, which impose technical and financial difficulties, particularly when using solar heating systems in vertical housing; and
4. Evaluation of the ways to train users to achieve efficient individual water metering.

2.2.2 Rainwater harvesting

a) System definition

The main function of the rainwater harvesting system is to reduce the consumption of potable water supplied by the concessionaires (in this case, SABESP), by using treated rainwater for non-potable purposes. This system ensures rainwater collection from waterproof areas, usually roofs, and its treatment and storage in accumulation reservoirs for subsequent utilization (MAY, 2004).

Collected rainwater is used most commonly in residential dwellings for non-potable purposes, such as:

- Flushing of toilets;
- Washing of vehicles and floors;
- Irrigation of green areas;
- Backups for firefighting in buildings.

Figure 26 shows an example of rainwater collection system.

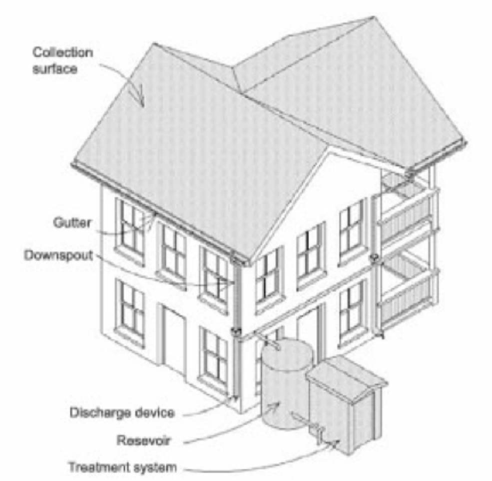


Figure 26 - System for collection and use of rainwater. Source: MIERZWA (2010)

Another benefit obtained from the retention and use of rainwater is a reduction in the quantity of water drained to urban systems, by the construction of small reservoirs (pools), avoiding the system overload during heavy rains, which can result in flooding and inflict heavy damage on society.

State law on pools, Law No. 12,526, from January 2nd, 2007, establishes standards for the containment of floods and disposal of rainwater and obliges to implement systems for capture and retention of rainwater, collected from roofs, coverings, terraces and open areas, in plots, regardless of whether they had been built, with a waterproofed area of over 500 m².

The main objectives of this law were:

- to reduce the runoff speed of rainwater into the river basins in urban areas with high soil impermeability coefficient and drainage problems;
- to control occurrence of floods, as well as damping and reduction of problems with flood flows and, consequently, the extent of damages;
- to contribute to reduction of consumption and to appropriate use of treated drinking water.

b) History of implementation

The CDHU project team observed that the use of rainwater for non-potable purposes is feasible only in housing developments with roof area for water collection of at least 300 m^2 and, therefore, this action is restricted to large undertakings.

In the Jardim Pantanal development, located in the capital of São Paulo, rainwater has been used to irrigate the local seed nursery. Similarly, this use has been adopted in parks built by the CDHU.

Currently, there are ongoing studies on the use of rainwater for toilets in the housing developments, using a simple mechanical filter for water drainage.

On the other hand, retaining rainwater to reduce the volume of water drained to the urban drainage systems has been carried out through small pools located in the housing developments. These reservoirs keep the water for a certain time period, and afterwards discharge it slowly into the city's rainwater drainage system.

The volume of these pools is calculated using the area of the land, the rainfall index and the time of duration of the rain, according to the following formula:

$$V = 0.15 \times AW \times RI \times t$$

Where:

V = volume of the reservoir in cubic meters;

Aw = waterproof area in square meters;

RI = rainfall index equal to 0.06 m/h;

t = time of the rain duration equal to 1 (one) hour.

The ABNT NBR 15527 (2007) technical standard offers several models for calculating the reservoir capacity for rainwater use for non-potable purposes, which does not necessarily coincide with the formula mentioned above.

c) Results

The installation of a system for collecting and using rainwater requires a hydraulic project separated from the system for potable water, in order to avoid water contamination. It requires more channels, more pipes, separate and identified outflows and a reservoir for the rainwater. Another requirement of this system is the guarantee of minimum quality of this collected water, thus the need for a treatment system.

Therefore, this system requires high investment for its implementation and maintenance. However, the rainwater harvesting leads to a reduction in the consumption of the water supplied by the concessionaire, resulting in a smaller condominium cost for the user.

The rainwater collection system to reduce the volume of water drained into the urban drainage system also imposes high implementation costs, but it enables reduction in the governmental expenditures for maintenance and construction of new urban infrastructure. In the case of the city of São Paulo, this action is very important due to the problems of floods, which occur mainly during the summer.

Finally, the CDHU Project Manual (CDHU, 2008) recommends that the housing development projects provide for retention reservoirs to meet current legislation and include a project to reuse part of the collected rainwater, at the discretion of the CDHU.

d) Challenges

The main challenges are:

1. Maintenance Cost: the rainwater harvesting system should be rigorously monitored and maintained. Furthermore, the biological, physical and chemical parameters of the quality of the stored rainwater should be monitored systematically (OLIVEIRA et al., 2005). All of those procedures demand specialized technical staff, increasing the cost of the system operation.

2. Need for user training: to prevent the user from being contaminated with rainwater, as it is only for non-drinking purposes.

3. Use restriction due to the meteorological characteristics of the area: in regions where there is a large interval between rainy seasons, the execution of rainwater use systems is quite expensive, as a very large reservoir has to be built to store the rainwater. This element substantially increases the cost of execution of the system, making it, in most cases, infeasible (OLIVEIRA et al., 2005).

2.2.3 Water saving devices

a) System definition

This solution is based on using hydro-sanitary devices and equipment that use less water for their operation, in comparison with conventional equipment. Among these are faucet aerators, flow regulating valves, flow limiter valves, toilets coupled with a reduced volume flush tank, double flush valves and tanks, used in residential and commercial buildings. Figure 27 shows examples of water saving devices available on the Brazilian market.

b) History of implementation

Currently the use of water saving devices available on the market, such as limited volume (6.8 liters) flush tanks and faucet aerators, are standard for the CDHU, being used in all units built. A wide array of water saving products is available, but the important thing is to use the technology that is most appropriate to the specific use for that kind of user.

The toilets, for example, went from using 12 to 18 l of water per flush to 6.8 l since 2004. This reduction occurred through the regulation of the ABNT NBR 15099 (2004) standard, which required the standardization of all of the ceramic tanks manufactured by the industry.

The PBPQ-H (Brazilian Program for Quality and Productivity in the Habitat) is assessing the possibility of reducing this volume, but a careful analysis has to be made so that it will not have an impact on the public sanitary sewage system.

Any new mechanism for reduction should undergo a careful evaluation so that the integrated system, that is, the sanitary bowl and the flush mechanism, works appropriately and do not cause any type of negative impact on the performance of the public system.

c) Results

Many of the water saving devices require a low initial and maintenance investment and do not generate significant impacts on the total cost of the building, in addition to have proven efficiency in reducing water consumption. They are well accepted by the users and have a consolidated market in Brazil.

Some devices, such as the double flush tanks, require constant cleaning of the membrane existing in the equipment to ensure correct operation. This device and others that require greater maintenance attention should be studied carefully as to their applicability in social housing, since in order to ensure their correct operation, the user must receive instructions on how to operate and maintain the equipment, which requires strong post-occupation education.

d) Challenges

The use of water saving devices is already consolidated in Brazil, including in the social housing sector, mostly due to its low implementation and maintenance costs and because they bring palpable benefits to the user's water bill.

However, as mentioned by Oliveira et al. (2005), in order to achieve a more effective reduction in consumption, awareness raising campaigns have to be developed so that users conserve water and use the water saving devices correctly.

Figure 27 - Water saving devices: double flush valve, 6-liter flush tank, aerators and flow limiter valves.
Source: DECA (2010)

2.2.4 Phyto-treatment

a) System definition

Also known as soil filters or Wetlands, these are systems that take advantage of the filtering characteristics of prepared soil to carry out treatment of domestic effluents (OLIVEIRA et al.; 2005).

This system is composed by a ditch filled with layers of sand, granular fill and the preparation of a highly alkaline soil where a "grid" of drains is arranged in the deepest layer and another grid of dispersers in the most superficial layer.

The process of decontamination of the reused water becomes more efficient when vegetation like reeds or Typhae is planted on the surface of the area intended for effluent discharge. The vegetation creates ideal conditions for the proliferation of bacteria, improving the biological processes of degradation of the organic load. Figure 28 shows a diagram containing the phyto-treatment system.

b) History of implementation

The use of phyto-treatment systems is under study in the CDHU, as well as the definition of the places where the project will be implemented.

c) Results

There are no results yet as this system is still being studied by CDHU. However, Oliveira et al. (2005) observe that this treatment system has the advantage of saving electricity, since it operates in a natural process. Another advantage of this system is that it also provides infiltration of rainwater that falls on the filtering area. Its treatment performance is generally good, enabling the production of reused water for toilet flush systems, irrigation of gardens and washing of floors. However, it becomes restrictive in the case of social housing because of the small area of land available in the plots.

d) Challenges

The main challenge of the action is to have a correct understanding of the technology, which requires appropriate dimensions to treat part or all of the sewage generated in the housing development.

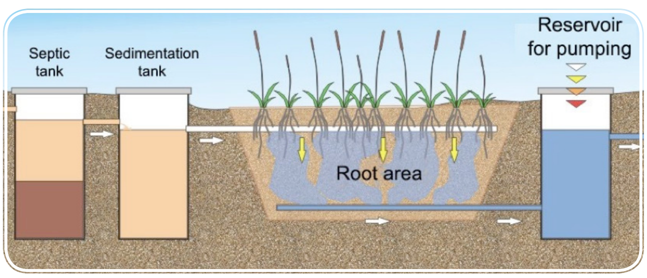


Figure 28 – Phyto-treatment system.
Source: OLIVEIRA et al. (2005)

2.2.5 In situ sewage treatment

a) System definition

In situ sewage treatment is provided by compact stations or septic tanks with anaerobic filters, which treat the sewage in the place where it was generated. According to Gonçalves et al. (2005), the compact stations are industrially manufactured modular systems with extensive applications, from single family households to large residential complexes.

Those systems enable sewage treatment and reuse of the treated effluent for purposes such as irrigation of gardens, car washing, cleaning sidewalks and flushing toilets and urinals. They can also remain entirely under the surface of the soil, without constraining the use of this area for other purposes, such as parking areas, gardens, playgrounds etc. Figure 29 shows an example of a compact station in situ treatment supplied by the Mizumo Company.

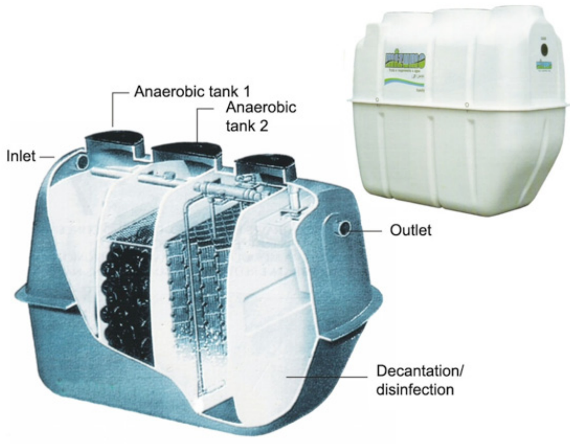


Figure 29 - Compact Mizumo station, Family line.
Source: GONÇALVES et al. (2005)

b) History of implementation

In situ sewage treatment is implemented by the CDHU in its undertakings in places where no sewage treatment is carried out by the water concessionaire.

In this case, CDHU meets all the requirements and guidelines of the public agencies for treating sewage in situ and takes the treated effluent to the sewage system of the water concessionaire or straight to discharge in streams (regulated by the DAEE – Water and Electricity Department), according to the quality guidelines established by the environment agency (CETESB).

In addition to considering the technical factors, definition by the type of in situ treatment is also guided by the smallest price. Among the factors that make the cost of the compact station competitive, when compared to septic tanks with anaerobic filters, are the quicker implementation time and the absence of concreting and excavation processes for opening ditches.

When CDHU adopts the compact station solution in its undertakings, it seeks to implement it in an institutional or commercial area, allowing for later donation of the equipment and the area, in which it is installed, to the water concessionaire. The main concern is to avoid installing the equipment in the condominium area, in order to spare the residents management and maintenance.

Nevertheless, in CDHU's history there are cases of implementing in situ treatment in condominium areas, when the responsibility for overseeing the treatment is left to the residents. Treatment with a septic tank and anaerobic filter, located in the condominium was mentioned, for example, in the buildings constructed by Caixa and acquired by CDHU, in the municipality of Praia Grande, and intended for the resettling of residents of the Serra do Mar program. Compact stations have also been implemented within condominium areas, such as the Bolsão 7, in the municipality of Cubatão.

However, in situ treatment in undertakings is considered to be temporary until installation of a treatment system by the water concessionaire.

c) Results

This system has the advantage of reducing the sewage load discharged directly or indirectly in the water bodies, in the cases where the water concessionaire did not implement a sewage system or even a sewage collection system.

However, the cost of implementation and, particularly, maintenance of these systems is high. Although each project has its specific dimension as a function of its population, kind of purification and other variables, the average cost of implementation of a treatment station is thought to be in the vicinity of R$ 1,000.00 per housing unit.

Furthermore, CDHU reports problems in the management of these stations, given that maintenance is quite complex and requires specialized technical personnel.

d) Challenges

The main challenge of this action is to have a suitable management of in situ treatment system, which requires an adequate treatment of the effluents in order to adapt to the potability standards required by the existing legislation. The operation has to be monitored in order to ensure that it will not disturb future residents.

In addition, maintenance will have to be preventive and a program to monitor the quality of the treated effluents will have to be established with the local concessionaire. Specification of the system materials and components should meet a series of technical requirements that ensure the quality of the system and safety of the users. Finally, in this kind of undertaking, condominium users should become water administrators to ensure the adequate use of the resource and reduction of effluent generation.

2.2.6 Permeable pavement

According to Oliveira et al. (2005), permeable pavements are simple infiltration systems, where the surface runoff is diverted through a permeable surface to the interior of the soil by means of an infiltration process.

Currently, the CDHU Landscape Manual recommends that the paved area be minimized, leaving as much permeable soil as possible, whenever feasible. Furthermore, the choice of pavement should consider the various uses in the project. The specification criteria should consider the aesthetic quality, durability, the ease of maintenance and the permeability to rainwater. The use of draining elements, such as lawns, pebbles, articulated paving, etc. should be preferred (CDHU, 2008).

CDHU technicians suggest technologies of water-bound macadam, interlocking pavers and "gramacadam". The latter is a simple technology, under CDHU development.

2.2.6.1 Water-bound macadam

a) System definition

Water-bound macadams are a type of pavement built from large elements with variable diameter, compacted, with particles firmly integrated to each other, and the empty spaces filled by material such as stone dust or sand, with the aid of water. The stability of the layer is achieved by the strong mechanical action of compacting.

b) History of implementation

CDHU is studying the use of water-bound macadam in the parking areas of its housing developments. Grass is to be planted over the final layer of the water-bound macadam, and the area will only be available for use after rooting. The place where the pilot project is to be implemented is still being studied by the CDHU.

c) Results

Although there are no results since there has not been a pilot project for water-bound macadam, results exist for its application in other areas. Thus, this paving provides the necessary resistance for low weight vehicles, such as cars and motorbikes, and its maintenance cost is low. Moreover, in the case of rain, it reduces the rate of surface runoff, since it is permeable, reducing the overload of the urban rainfall drainage system, generated by impermeability of soils.

Another benefit is extended green area, providing thermal comfort for users and reducing the effects of the urban heat islands, since this pavement does not absorb and reflect solar radiation like concrete or asphalt. However, this pavement usually requires higher initial and maintenance investments than concrete or asphalt.

c) Challenges

The main challenge of this initiative is maintenance, since the CDHU agreements with the contractors require that they carry out landscape maintenance for 2 years after the housing developments have been delivered. After this date, maintenance is the responsibility of the condominium, which often does not carry it out like it should.

2.2.6.2 Interlocked pavement

a) System definition

Paving with pre-molded concrete blocks is a modern and improved version of the old paving stones. Figure 30 shows an example of interlocked pavement.

b) History of implementation

One of the first CDHU experiences with specification for the covering of a parking area with interlocked pavement was held in 2004 in the Itaquaquecetuba[18] B2 and B3 housing developments, in a joint community effort. However, that undertaking still has not been concluded, due to the problems with the community efforts.

In São Sebastião E, an undertaking initiated in 2005 and delivered in July 2008, interlocked pavement was also used. Among the recently delivered undertakings using interlocked pavement and grass in the parking spaces, is Ribeirão Preto[19] B2/B3, delivered in 2010.

With the increased number of trees in parking areas since 2005, the use of grass in the parking slots became part of the project specifications, as well as the use of interlocked pavement. At present, the CDHU

Figure 30 - Permeable pavements using interlocking blocks. Source: TECPAV (2010)

Landscaping Manual recommends that circulation in plazas and condominiums should be in straightened concrete or concrete interlocked pavement (CDHU, 2008).

c) Results

Positive aspects of the use of this action include good resistance and durability of the pavements and possibility of use directly after placement, easy construction and, maintenance and safety since they are nonskid.

d) Challenges

The main challenges are pavement maintenance, avoiding infestation of invasive plants and the diffusion of techniques other than weed-killers, whose use has recently been banned in urban areas.

2.2.6.3 "Gramacadam"

a) System definition

A stony and porous base made from compacted elements, similar to the water-bound macadam in its assembly and components. The difference is in the more discontinuous granular fill layer, with greater number of empty spaces and absence of the filler – a water and stone dust paste, which fills the empty spaces in the water-bound macadam.

Here, the filler is partly replaced by agricultural substratum, which loosely fills the stony layer, so as to preserve part of its porosity to air and water. Sod squares are planted as covering; when the roots reach the subgrade, the pavement is ready for loads.

This period is still being assessed, but it is estimated between three and six months.

b) History of implementation

Recently, the technique was used in the leisure area of an undertaking in São Vicente , São Paulo (C.H. Mexico 70). However, an agreement with the IPT (Institute of Technological Research) is up for renewal to fully evaluate and develop the technology.

c) Results

This technique is still under evaluation. The application in São Vicente is of minor scale than the intended ones, since it is only planned for pedestrian traffic. Originally, the technique was conceived for parking areas, which require greater load capacity, still to be assessed.

d) Challenges

It will be necessary to carry out tests for all possibilities of the technique: methodology, materials, costs, schedules and evolution of the load capacity, maintenance and life cycle, reversibility, etc.

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18 Itaquaquecetuba belongs to the Metropolitan Region of São Paulo. It is located in the south-east region of the state of São Paulo and has about 320,000 inhabitants.

19 Ribeirão Preto is located in the northeast region of the state of São Paulo and has about 605,000 inhabitants. It is one of the richest cities in the state.

2.3 Landscaping: Natural Shading

a) System definition

Landscaping projects are used to improve the thermal comfort of the social housing and to integrate housing developments to the urban environment. Natural shading consists of creating natural shields, instead of using the artificial ones such as metal covers, in order to decrease the incidence of solar rays on soil and vehicles, reducing heat island effects.

b) History of implementation

The first pilot project using natural shading for parking areas was carried out in Ribeirão Preto B2/B3, initiated in 2005 and delivered in 2010. Other experiences have also been carried out :

- Jaraguá D (in western area of the São Paulo City) was delivered in 1998 and it preserved a large extension of existing vegetation and permanent preservation area within the condominium (15-story buildings).
- São Sebastião E was delivered to people from a dismantled slum, and permanent preservation areas were kept within the condominium, but we do not know much about the present situation. This case should be monitored, to see if the population is maintaining the natural shading areas.

Currently, CDHU has a large project in Guarulhos in the implementation of its initial phase, which includes urbanization of invaded areas with the construction of new units to free the Permanent Preservation Areas, sanitation and recovery of streams, implementation of a public park to preserve the remaining forest and recovery of the stream preservation area.

c) Results

This action reduces urban heat islands. Moreover, after planting trees, the maintenance cost is practically zero, according to the team responsible for CDHU's landscaping projects.

CDHU recommends avoiding trees with fruits or flowers that are detrimental to a person's health, as well as those that might be dangerous to users due to their size. The use of vegetation should be compatible with the installed infrastructure, either above or below ground. Its roots should remain far from gutters, channels, etc. (CDHU, 2008).

On the other hand, given the limited space for parking, planting trees in the area of the undertaking will result in less parking area. Another impact caused by this initiative is the reduction of the efficiency of external night lighting, obstructed by trees.

For this reason, CDHU also recommends that the vegetation used consists basically of trees and ground covers, avoiding the shrubs that form bushes. These should not be planted in public spaces, when used in condominiums.

d) Challenges

The main challenge of this action is to find area for shading of the housing development areas with the use of trees. Even in the case of multi-story buildings with increased available area, the buildings are low and require one garage parking space per apartment, which greatly increases the demand for parking area.

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20 São Vicente belongs to Baixada Santista and has a population of approximately 332,000.

2.4 Design and construction

In addition to sustainable actions in the areas of water, energy and landscaping, the CDHU technical staff mentioned in the interviews several sustainable actions that are being undertaken in the design phase. Below are some of the CDHU project initiatives in the area of sustainability.

2.4.1 Modulation

a) System definition

Modular coordination is the technique that allows establishment of horizontal and vertical dimension of environments starting with a basic module (MANZIONE, 2004). This implies that both the height and the width of walls will be made up of multiples of the dimensions of the blocks used to create these elements.

According to Razente (2004), the fact that the block dimensions are known and have small variability allows the use of the modular coordination technique. This technique consists of defining all the dimensions of the work, both vertical and horizontal, as multiples of the dimensions of the basic unit, including frameworks and other installations. In this way, cuts and wastages during construction are avoided. This procedure is an essential stage in the process of overall rationalization.

b) History of implementation

The modular coordination technique has been used in social housing since the mid-60s, when the use of blocks began.

c) Results

The most evident benefit of block modulation is the reduction of material losses that arise from manual cutting of blocks, and an increase in productivity of the mason. (FRANCO, 2000). The main factor constraining the structural masonry is that this restricts architectural possibilities of a building, since it must be adjusted to the modulation used in the masonry blocks.

CDHU currently works with modulation of all systems. One of the technical guidelines, as defined in its Technical Project Manual, is to seek to define the dimensions of the environments within a modular coordination system, adapting the modulation to the adopted building system. Preferential for adoption are components that are available in the market, such as doors and windows (CDHU, 2008).

d) Challenges

The main challenge of the action is to allow architectural variation, according to the characteristics of each place where the housing development is to be built, within the constraints of the modulation.

2.4.2 Electrical and water kit

a) System definition

It is based on the pre-assembly of components such as pipes and conducts by the suppliers according to the water and electricity design for the undertaking developed by CDHU, in order to eliminate this production stage from the work site and speed up the installation of these components in the buildings, already standardized and numbered according to the installation sequence.

b) History of implementation

The first project was implemented in horizontal housing developments in the municipality of Potim[21], in 2002, with a donation of 60 kits from the suppliers for an undertaking of 299 housing units.

c) Results

The main benefits from the water kit as a building method are productivity increase, improved quality of the work done and reduction of the losses and waste generated at the building site.

d) Challenges

The main challenge of this action is that suppliers become interested in adopting the use of this concept, with the rationalized delivery of standardized components that are numbered, according to the installation sequence.

2.4.3 Concrete walls cast in loco

a) System definition

The wall is concreted in forms that are subsequently replaced with frames, bolts and affixed to polyurethane foam.

b) History of implementation

The first pilot project was applied in Peruíbe, coastal city of the state of São Paulo. CDHU usually holds public tenders for the construction of the housing developments requiring structural masonry, which is its standard construction technology. However, the selected company may use any type of structural and sealing system that is certified by Qualihab. In this case, the selected company decided to use concrete walls cast in loco.

c) Results

The use of concrete walls cast in loco was accepted by the CDHU, however, no study was carried out to evaluate the environmental performance and cost of the use of this system, since it was not the masonry standard requested by CDHU.

21 Potim is located at eastern of the state of São Paulo, which population is about 20,600 inhabitants.

2.4.4 Laminar buildings

a) System definition

These are rectangular buildings currently used by CDHU to replace H-shaped buildings.

b) History of implementation

H-shaped buildings are considered the most economical and rational because of the possibility of smaller corridor and elevator areas, increasing area available for apartments. However, these typologies require large areas, increasing costs of land leveling.

Since the supply of lands in the city of São Paulo has decreased in the last few years, leading to the occupation of areas with greater slope, it was decided to use laminar buildings, although they are not as economical or rational, but they require less area for the implementation.

One of the first projects for laminar buildings was in the Serra Negra municipality.

c) Results

The main results are smaller land leveling costs, but since the area for corridors and elevators is increased, the building cost also increases.

d) Challenges

The main challenge of this action is to design laminar typologies that have lower land leveling costs, but are as economical and rational as the H-shaped buildings.

2.4.5 Universal Design

a) System definition

Use of Universal Design in a project consists of creating environments and products that can be used by everyone, to the maximum possible extent (Government of São Paulo, 2010).

b) History of implementation

CDHU presents the reference parameters that should be adopted by the hired designers through procedures for the definition of project guidelines with Universal Design in the housing units, in the common condominium areas and in the urban public areas. At present, all of CDHU projects use the concepts of Universal Design, including the housing developments that are part of the Program for the Socio-Environmental Recovery of the Serra do Mar. The first pilot project was carried out, in 2010, in Avaré[23], by the Program Vila Dignidade, for housing for the elderly, with 24 housing units.

c) Results

Results show an improvement in the quality of the housing when the Universal Design concepts are adopted. Nevertheless, an increase in the cost of the building was also seen.

d) Challenges

The main challenge of this action is to relate the concepts of accessibility with those of sustainability, since it is not always possible to achieve 100% accessibility with the requirements imposed by existing environmental legislations.

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22 Serra Negra is located at the east region of the state of São Paulo, near de border of São Paulo and Minas Gerais, another Brazilian state. It has about 25,700 inhabitants.

23 Avaré is located at west region of the state of São Paulo and has about 82,900 inhabitants

2.5 Quality and sustainability: QUALIHAB Program

a) System definition

QUALIHAB or the Program of the State of São Paulo for Quality in Housing Construction was developed and is coordinated by the CDHU. Established in 1996, the program, a pioneer in issues related to quality and productivity in Brazilian civil construction industry (JESUS, 2004), was used as a basis for another nationwide program, the PBQP-H, Brazilian Program for Quality and Productivity of the Habitat.

The main objective of this program is to ensure the quality of the housing built by the state, in all phases, from concept right through execution, under the principle that the low income population has the right to good quality housing that is durable and expandable, to meet the needs of a growing family (CDHU, 2008). Its guidelines are based on three interconnected actions: training of the workforce, development of technical standards and implementation of quality management systems.

The CDHU uses, through QUALIHAB, its purchasing power to require certification of its suppliers and to encourage the pursuit of quality in civil construction in the state of São Paulo (JESUS, 2004), in addition to raising the quality standards of social housing, even though in this kind of undertaking the concept of lowest possible price is paramount.

b) History of implementation

This program is applied to all systems and products used in the CDHU housing developments.

In August 2007, QUALIHAB formalized the activities for evaluating construction systems, materials and components, with the creation of the CAMCS (Commission to Evaluate Materials, Component and Building Systems). With CAMCS, QUALIHAB/CDHU intensified the processes for receiving proposals and evaluating the technological improvements and innovations for CDHU works and services.

In order to provide support for inserting socio-environmental criteria in social policies, in consumption patterns and in hiring within the public administration of the state of São Paulo, QUALIHAB relies on a legal framework established by the state government, through the Socio-environmental Seal (Decree No. 50,170, dated November 4th, 2005) and by the State Program for Sustainable Public Hiring (Decree No. 53,336, date August 20th, 2008).

c) Results

As one of the results of this program (CDHU, 2008), CDHU requires in its public tenders that the companies, who already have sector-specific quality agreements, comply with the sector programs and technical standards, and prove their qualifications, as conditions for participating in its housing developments.

Furthermore, the model developed in São Paulo is being adopted by others states, and also by the Planning Secretariat of the Federal Government, through the PBQP-H - Brazilian Program for Quality and Productivity – Habitat.

Among the 44 agreements already signed by QUALIHAB with sector entities, is one with the entity that represents the solar water heaters sector (ABRAVA) and the Brazilian Association for Environmental and Sanitary Engineering (ABES).

Finally, the Caixa, inspired by the program, decided to require quality certification of the construction companies in order to finance housing. This requirement went into force in July 2001.

2.6 Social

Although the scope of the SUSHI Project only included assessing water and energy as pilot functions, during the interviews with the CDHU staff the need to evaluate the education work carried out to insert sustainable technologies in social housing was also observed.

The social area of the CDHU had different guidelines for action, according to the state government planning, for the construction of social housing, in the different periods.

During the state government of 1983 to 1987, the focus of the CDHU was production of homes in horizontal housing developments. Since not enough resources were available to meet a wider range of demands, services were small-scale. Thus, the Joint Community Effort Program for Housing was often used to reduce the production costs. The state government supplied a basic set of building materials and the houses were built by the community over several years. In this case, the social area followed the entire construction of the housing development and had a major role within the company.

Since 1990, resources grew with the ICMS-housing, which increased the collection of this state tax by 1%, and most of this increase went to the construction of social housing. Thus, the CDHU now had financial resources to carry out large scale housing services centered on reducing the state's housing shortage. During this period, lands began to be amassed, with the acquisition of large fields, for the construction of housing developments. Furthermore, given the large production scale of social housing and the adoption of housing programs based on subcontracting of construction companies, the community building program became less important and the operation of the social area was reduced.

During the state administration of 1995 to 2001, the community building program was once again taken up by the state government, and it was extended to the production of buildings in vertical housing developments. However, unlike the period of 1983 - 1987, the community building programs acquired new formats, through the transfer of CDHU resources to the community associations – in the case of the metropolitan region of São Paulo. In this management model, the community associations were responsible for managing the resources, while CDHU was responsible for their oversight. The social area of CDHU remained less important, restricted to the oversight of the management of the community joint effort programs, which came to be developed by social workers, hired by the community associations to meet their members' needs.

This management model also led to many distortions due to the lack of management training of these associations. Furthermore, building housing in joint community programs also led to several construction problems.

In the current administration, CDHU actions in the social area are divided into two sections, the first in the urbanization and recovery of existing slums and the second for post-occupation work in the newly built housing areas.

The joint effort community building program was transformed into the Shared Management Program, where the production of the hydraulic and electric structure of the houses is carried out by outsourced companies and the completion works by the residents themselves. In this way, resident associations receive little financial resources from the state, and in order to receive them, they have to undergo a judicious selection process, which reduces management problems.

2.6.1 Re-urbanization of slums

The urban recovery section acts in the urban-environmental recovery of slums by keeping as many existing buildings as possible and ensuing preservation of the social connections that have already been established by the residents. To do so, it uses several management tools, such as social projects and mapping of social indicators.

An important example of CDHU action in this area is the Pantanal Project, in the city of São Paulo, whose objective was to urbanize the centers of União de Nova Vila and of Vila Jacuí, located in the extreme east of the city of São Paulo, in an area affected by severe floods in periods of intense rains. Beyond the removal of the population from the areas at risk of flooding and their adequate settlement in social housing, several actions were carried out that contributed to social inclusion of the residents, providing support to urban-housing intervention and improving its sustainability.

Figure 31 shows pictures of the recycling cooperative created in the Pantanal Project

Among these actions, particularly significant are the following projects:

- Training of community agents and community teachers: aims at building the capacity of the representatives elected by the population and the representatives of the local production groups to act as multipliers of the concepts of citizenship and democracy, information and social development, education and environment, etc., to the community, encouraging reflection on the changes going on in the neighborhood and resulting in the formation of a network of agents capable of identifying problems, proposing solutions and involving the entire population in the process of urbanization and renewal of the neighborhood. Training of community teachers was done in partnership with the Popular Center for Culture and Development – CPCD.

- Local development network / Course on entrepreneurship in small businesses: partnership between CDHU and the National Service for Commercial Education of the State of São Paulo (SENAC-SP) to promote concrete mobilization actions, training processes for professional qualification and jobs and income generation.

- Project “São Paulo de Cara Nova”: provides for the recovery of houses and public areas by landscaping and implementation works and/or recovery of urban and leisure furniture and enhancing the aesthetic value of houses through urban-art.

- Project “Amigos da Praça / Amigos do Parque”: aims to preserve and ensure the community and democratic use of public spaces for sharing and leisure, by creating activity commissions and programs involving all segments of the beneficiary population.

Figure 31 - Cooperative of recycling created by the Project Pantanal. Source: CDHU (2010)

- Recycling Cooperative "Nova Esperança": the project aimed at implementation of waste sorting within the Pantanal Project, so as to generate income for the cooperative and reduce the volume of residues deposited on the Tietê banks, streams and public roads. Together with urban infrastructure works, it contributed to the containment of floods. The project promotes socio-educational campaigns and activities focusing on environmental awareness and mobilization of the community. CDHU provided an area and the construction of a shed for sorting the wastes and to house the Cooperative, according to the Ministry of Cities guidelines. The 34 scavengers, that form the cooperative today, have been trained in production techniques and in cooperative management in partnership with the Institute GEA – Ética e Cidadania. Currently the cooperative produces monthly around 40 tons of recycled material. It counts on several partnerships and has received various recognition awards.

- Sustainable Development Forum: integration of resident associations, local entities, leaders, urban community agents, NGOs, public agencies and concessionaires, aiming to prepare the community for shared self-administration of the new urban area, in order to ensure the sustainability of the social, physical and political conditions of the intervention.

- Community newspaper: partnership between the CDHU and the community to produce local newspapers with the required capacity building of the participating residents, through journalism workshops and techniques of community communication.

- Project Tenda Itinerante: targeted to all residents of the Pantanal Project, the Tenda Itinerante (traveling tent) went to several areas of the neighborhood raising awareness and disseminating the urbanization process in dynamic and participatory manner, helping the population to take part in the ongoing actions.

- Project CADS (Supporting Center to Sustainable Development): project for local sustainable development based on the generation of work and income, environmental education, formation of art and education groups and creation of a traders association.

2.6.2 Post-occupation social management

The social team develops actions during the "post-occupation" stage of the housing developments, in order to inform the beneficiary population and prepare them for the suitable use of the houses and collective areas, for the participation of community and condominium organizations, and for the respect of environmental aspects.

Bearing in mind CDHU's trend towards building vertical developments in the last few years, together with the fact that low income families, particularly those removed from risk areas, have no experience in living in buildings with these characteristics, one of the main tasks of the Social team is to train these families to understand the changes through which they will go in moving to these environments and living in condominiums. The Social team prepares the families and leaders to understand the legal concepts that affect Brazilian condominiums and, in accordance with this legislation, teaches them on how to create such a condominium legally, elect a house manager and management body, establish condominium budget, record and store documentation, obtain a condominium tax ID, among other actions that are essential to organize these communities.

To do so, staff from the CDHU social area together with those from the commercial area, begin their work with a meeting in order to explain to the new residents the procedures to acquire the building and the first concepts of life in a condominium. After that meeting, another one takes place on the day the contract is signed, when the social team informs the users of which bills they will be responsible for; and from then on, they are encouraged to set up the first representative commission.

After the families have moved in to the housing development, the social team promotes a series of meetings to prepare the families for the condominium organization with more details, as well as to encourage their conscious and active participation in the election of the house manager and the assembly to install the condominium.

This follow up by the CDHU social team remains in place until the house manager is elected and the documentation related to the condominium installation is registered. Afterwards, the social team also promotes a series of capacity building sessions of the house managers and commissions and, from then on, if the condominium so desires, it can hire an administrator to continue the management work.

As to the education activities for the use of sustainable technologies, CDHU distributes information material on rational use of water and individual metering and it disseminates an educational video on the issue. However, it does not actually train users to use and maintain all adopted technologies, due to the lack of personnel and the demand for specialized technicians, in some cases with specific education, that might not be a part of the social team. It also provides information materials on the care required in the use of cooking gas, handling of domestic garbage and sharing of common areas, like parking. In addition, the social team together with the construction team promotes capacity building on the use of condominium equipment, such as fire extinguishers, electricity and gas metering centers, how to read the meters, management of water pumps, emergency lighting, use and maintenance of common areas, among others.

The Social team, in addition to the typical 'post-occupation' activities, develops other actions such as the Urban Insertion Diagnosis of the lands being acquired, sending these studies to the lands team. These studies verify the impact that construction of a building will have on the neighborhoods, particularly in public services such as education, health, transport, and supply, among others. These studies aim to guide both the social team and the project team in actions to minimize these impacts and to help the families that move to the new development encounter fewer difficulties in inserting themselves in their surroundings and receive the necessary services.

The Social team also manages all non-housing plots of the undertakings that are not used, particularly the institutional areas, fostering their appropriate use for building schools, health centers and other facilities necessary for low income populations.

From their experience with residents, the Social team raised some issues as to the sustainable aspects of social housing built by the CDHU:

- The social housing designers should incorporate data from the Urban Insertion Diagnosis on the neighborhood infrastructure into the housing development projects and thus more precisely design the institutional areas that will be part of the urban projects in order to meet needs of local populations;
- One should not only think of the sustainability of the building, but also on the sustainability of the urban project of the housing development, and its impact on the town;
- Sustainable technologies should be inserted, respecting that, in many cases, there will be a need for a change in the habits of the users that are going to make use of these technologies. For this reason, a specific capacity building program is recommended for each new technology that is adopted or for the technologies that are not part of the day-to-day routine of these families;
- The adoption of sustainable technologies should take into account the cost of implementation and maintenance of these technologies and be in line with the financial capacity of the users; and
- In order to implement a specific technology, the availability of replacement parts and equipment should be examined.

Finally, the CDHU has been concerned with increasing the operation of the social area in social housing as a way of improving the socio-environmental quality of its projects. Thus, the company held a new public tender (032/2010) to hire specialized technical services for social and condominium organization of the residents of CDHU social housing that are or that will be registered municipal condominiums, as defined in Federal Law No. 4,591/64 and by Chapter VII of Federal Law No. 10,406/02 of the new Civil Code. The difference between this new model and the model that the social team has been using until now is that the CDHU will hire condominium administrators to do this work; releasing the residents from paying the administration tax for the hired administrators. In this way, the Social team will be able to direct its focus to projects for professional capacity building, income generation and environmental education.

3 Cost of sustainability actions in social housing

In order to assess the increase in the implementation cost for sustainable actions in the standard CDHU housing, two cost simulations were carried out (RIZZO, 2010). The first simulation was carried out with single story houses, isolated and with two bedrooms. Three cases were studied:

- Case 1 – standard CDHU typology (TI 24 A) with two bedrooms and possibility of expansion to four.
- Case 2 – CDHU typology (TI 24 A-01 2d) with two bedrooms and possibility of expansion to four, modified with increased area, solar water heating system, slab lining and lining of walls in kitchen and bathrooms.
- Case 3 - CDHU typology (TI 23 E-01 2d) with two bedrooms and possibility of expansion to three, modified with use of metal roofing structure, aluminum frames and revision of some specifications.

The second simulation was carried out with single story houses, isolated and with three bedrooms. Four cases were studied:

- Case 1 – CDHU typology (TI 24 A-01 3d) with three bedrooms and possibility of expansion to four.
- Case 2 - CDHU typology (TI 23 E-01 3d) with three bedrooms, modified with use of metal roofing structure, aluminum frames and revision of some specifications.
- Case 3 - CDHU typology (TI 33 A-01) with three bedrooms, modified with increased area.
- Case 4 - CDHU typology (TI 33 B-01) with three bedrooms, modified with increased area, use of metal roofing structure, and aluminum frames use with larger areas.

Table 13 presents the cost increases and their distribution with the implemented actions.

Table 13 – Simulated cases to evaluate cost increase for implementation of sustainable actions in social housing

SIMULATION 1: isolated, single story house, 2 bedrooms												
Cases	Housing unit/ type	Area (m^2)	Area increase(%)[1]	Cost (R$)	Cost increase(%)[2]	Use of solar heating system(%)	Use of slab lining (%)	Use of lining (%)	Use of metal roofing structure (%)	Area increase (lining, painting). Complements (%)	Use of aluminum frames (%)	Revision of specifications (%)
1	TI24A	43.18		34,591.25								
2	TI24A-01 2d	48.89	13.22	51,477.13	48.82	12.39	10.25	9.00		17.18		
3	TI23E-01 2d	48.89		52,862.72	2.69				6.00		- 1.00	- 2.31
SIMULATION 2: isolated, single story house, 3 bedrooms												
Cases	Housing unit/ type	Area (m2)	Area increase(%)1	Cost (R$)	Cost increase(%)2	Use of solar heating system(%)	Use of slab lining (%)	Use of lining (%)	Use of metal roofing structure (%)	Area increase (lining, painting). Complements (%)	Use of aluminum frames(%)	Revision of specifications (%)
1	TI24A-01 3d	56.28		56,768.13								
2	TI23E-01 3d	56.28		58,986.85	3.91				6.81		- 1.20	- 1.70
3	TI33A-01	59.97	6.56	61,344.48	4.00					4.00		
4	TI33B-01	66.00	10.06	72,121.15	17.57				6.63	8.96	1.98	
										10.94		

Reference date: April/2010
Observations:
1 Area increase is always related to the previous case.
2 Cost increase is the sum of the increases for the use of the technologies and the area increase for that typology, and is related to the previous case.

According to Table 13, in the case 2 of simulation 1, the housing unit area has increased by 13.22% with respect to the case 1; from 43.18 m^2 to 48.89 m^2. The addition of the area and the use of a solar water heating system, slab roof lining and finishing on the kitchen and toilet walls led to an increase in the total cost of the unit of 48.62%, where 12.39% refer to the solar heating system, 10.25% to the slab lining, 9% to the finishing covering and 17.18% to the area increase.

In the case 3 of simulation 1, the area was not increased with respect to the case 2. On the other hand, in addition to the case 2 modifications, the use of a metal roofing structure, aluminum frames and revision of some specifications were adopted, which led to an increase of 2.69% in the total cost. The use of a metal roofing structure led to an increase of 6% in the total cost of the unit. However, the use of aluminum frames and the revision of some specifications reduced the cost by 1% and 2.31%, respectively.

For simulation 2, the case 2 had an increase of 3.91% in the cost of the unit, where 6.81% were due to the use of the metal roofing structure. However the use of aluminum frames caused a 1.2% cost reduction and the revision of some specifications reduced the cost by 1.7%.

In the case 3 of simulation 2, there was an increase of 6.56% in the housing unit area with respect to the case 2, from 56.28 m^2 to 59.97 m^2, which raised the cost of the unit by 4%.

Lastly, in the case 4 of simulation 2, the area of the housing unit was increased by 10.06% with respect to the case 3, from 59.97 m^2 to 66 m^2. The extra area, use of metal roofing structure and use of aluminum frames led to an increase in the cost of the housing unit by 17.57%, where 8.96% were due to the area, 6.63% to the use of metal roof structure and 1.98% to the aluminum frame used in the windows.

Furthermore, looking only at the cost increase resulting from the use of Universal Design, CDHU (2010) establishes percentages of increases in built area when compared with the prior production of SH/CDHU. The data of the average building areas, according to the adopted typology, are presented in Table 14.

Table 14 – Increase of average building area according to adopted typology

Typology	Area without Universal Design (m2)	Area with Universal Design (m2)	Area increase (%)
Single story house, 2 bedrooms	50	57	14
Single story house, 3 bedrooms	60	66	10
Apartment, 2 bedrooms	52.5	58	10.5
Apartment, 3 bedrooms	65	68	4.6

Source: SH/CDHU – Superintendência de Projetos (2009)

4 Conclusions and recommendations

The history of CDHU is marked by a series of events that characterized the way the company operates today - in a responsible manner and with the commitment not only to meet the housing demand in the State of São Paulo but also to aggregate sustainable technologies in order to reduce the environmental impacts caused by the growing population of the region.

This report discussed the issues of energy efficiency and the sound use of water, describing the experience of CDHU in implementing the solutions and its challenges related to equipment costs, discontinuity in the system use and awareness-raising among the population receiving the technology, among others.

In this way, it has been discovered that the implementation of new solutions and technologies, even though technically protected, require some time for adaptation to the building operation, as well for the capacity building of the final users.

Another important point concerns the quality of the components to ensure that the final users are not guinea pigs for new technologies. Public tenders already include the prerequisite of using products that meet Brazilian technical standards, but when dealing with innovative technologies, many of them do not yet have technical regulatory standards. Technical evaluation of these technologies is required not only to assess the characteristics of these products in the laboratory, but also to test their performance when applied. The objective is to identify their adequate use and to supply the manufacturers of these technologies with fundamental information to improve them, so that when disseminated they can be standardized.

To carry out a precise analysis of the benefit of a solution or technology, it is necessary to make a systemic evaluation of the conservation of inputs in buildings, since sometimes what benefits one input might harm another.

An Input Conservation Program (ICP) favors optimized use of inputs, bringing economic benefits, increasing the useful life of the systems, thus contributing to the sustainability of the building and to the environment as a whole.

An ICP refers to a set of actions geared to management of the supply and demand of inputs. If the program is implemented systemically, input consumption is optimized and, consequently, the volume of effluents is also reduced, as is the emission of CO2, among others.

4.1 Lessons Learned: solutions for rational use of water in social housing

In the case of water, the optimization of use (demand management) and the use of water with varying levels of quality to meet existing needs (supply management) protects public health and other related uses, all administered by appropriate resource management.

4.1.1 Benefits generated with solutions for rational use of water

The following factors are particularly important incentives for implementing an Input Conservation Program in the area of water resources:

- Savings generated by the decrease in water consumption;
- Savings generated by the reduction of produced effluents;
- Savings of other inputs such as energy and chemicals;
- Reduction of operational and maintenance costs of water systems and building equipment;
- Increase in the availability of water;
- Added value to the "product";
- Improved view of the organization in society – social responsibility.

4.1.2 Recommendations for projects related to the sound use of water

Within these concepts, the following are recommended:

- Greater technical detailing of the building hydraulic systems project with respect to individual water metering – interface with water heating systems;
- Greater technical detailing of the potable and non-potable water systems;
- Economic and technical evaluation of the use of water saving devices;
- Economic and technical evaluation of the use of alternative sources of water - use of rain water and reuse of water for the CDHU typologies, with risk analysis for management of the quality and quantity, safety and comfort of the users;
- Modeling of an educational policy for the users with regard to water supply and demand management, for effective use of the applied initiatives;
- Proposal for an incentive policy to create a basic set of hydraulic components to encourage the sound use of water;
- Development of a project, execution and maintenance manual, focusing on water supply and demand management in CDHU typologies;
- Proposal for a monitoring model for the CDHU undertakings by typology, so as to establish a ranking of the condominiums that carry out the best management of their inputs and perhaps establish a symbolic award.

In addition, the survey undertaken in this report shows the importance of systematization of the results of the technologies applied by CDHU for subsequent project development. It also shows that more detailed studies on the real performance of technologies are necessary, as is the access to a more completed database on energy consumption of households.

The final user is also considered a key element in the acceptance and maintenance of the applied technologies, showing the importance of future CDHU commitment to require, in their public tenders, educational projects for the user with respect to the preservation and maintenance of the technologies used in their homes.

4.2 Lessons Learned: solutions for energy efficiency in social housing

This report evaluated some technologies applied by the CDHU that are related to energy supply and demand management strategies. Nevertheless, some other strategies that had been initially mapped theoretically in the project and were not analyzed in this context could be stated as future recommendations for examination, since they could complement or enhance actions already practiced by CDHU. In each of them, the corresponding inputs should be considered, while carrying out a substantial evaluation of their cost-benefit ratio and sustainability characteristics.

4.2.1 Recommendations for energy efficiency (demand management)

Among the mapped demand management strategies that deserve further study, are:

- Current limitation for peak hours, which could be associated to ongoing studies on the use of solar heating systems with support from automated devices;

- Ceiling ventilators, incorporated to the strategy of supplying efficient electrical appliances for houses, based on a cost-benefit analysis, as well as the choice of refrigerators not just by their energy efficiency, but also by the refrigerant gas used to ensure it does not deplete the ozone layer;

- Possible use of integrated sanitary environments and technical shafts, incorporating the concept of loss reduction, increased productivity, industrialization and standardization of solutions, as well as increase in the durability of the systems;

- Possible delivery of housing units with semi-finished kitchen, as done in other countries, where efficient major household appliances, such as refrigerators and stoves, are already installed. The same strategy could be applied also to water saving devices, thus bathrooms would be delivered semi-finished with efficient equipment such as sinks, toilets and faucets, as well as worktop with sink in the kitchen. Colombia is an example of the application of this strategy with a fair amount of success, where houses are often delivered with finished/semi-finished kitchens, bathrooms and built-in closets in bedrooms. This is done not only for low income housing, but also for average and high income housing, the difference being in the type of finishing used;

- Proposal for a continued education policy for users on energy efficiency issues for the acquired items and their future maintenance, operation and replacement.

4.2.2 Recommendations for energy efficiency (supply management)

Among the mapped supply management strategies that deserve further study, are:

- Technical evaluation of the construction characteristics of the houses as a function of thermal performance and cost-benefit of the materials, as well as in the relation to the specification of walls, roofs, openings and possible strategies for action according to the context. Furthermore, the projects require compliance with the Brazilian performance standard for buildings of up to 5 floors (ABNT NBT 15575);

- Shading solutions for buildings with greater detailing of the systems used by CDHU and analysis of possible solutions with regard to cost-benefit, such as the use of hollow elements, differentiated openings, shutters and others shadings;

- Shading solutions that are independent of the construction systems and might be obtained for example through landscaping;

- Technical and cost-benefit analysis of the roof covering with various functions such as the use of green roofs or roofs with photovoltaic system. Proposal for a public policy for promotion of the adoption of these systems;

- And finally, proposal for the cost-benefit analysis of solar heating systems with regard to their performance and quality of materials and in comparison to similar technologies. Another important area for detailed study is the option of heat pumps with high performance coefficients as a technological alternative for water heating.

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This publication is the second in a series of three technical assessments developed during the implementation of the Sustainable Social Housing Initiative (SUSHI) in Brazil. This project aims at promoting the use of sustainable solutions in affordable housing projects in developing countries.
Following the initial assessment of the status of social housing in the State of São Paulo, the Urban and Housing Development Company (CDHU) expressed interest in reviewing the experiences already conducted to integrate sustainable elements in social housing projects. These experiences included, for example, replacement of equipment, modification of buildings´design or provision of alternative sources of water/energy.
This report presents the alternatives tested by the company, the results obtained, and the challenges encountered. This assessment allows to highlight potential benefits of solutions for energy efficiency and water management in social housing. Based on cost simulations and these previous experiences, this report proposes recommendations for future replication and adaptation of these strategies.
The third report of this series combines the results of the initial assessment with the lessons learned from CDHU's previous experiences, and provides an analysis of costs, benefits and efficiency of the alternatives selected to improve the sustainability performance of social housing units.

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