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Assessment

Assessment of market-available technologies and solutions to improve energy efficiency and rational use of water in social housing projects in Brazil

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CBCS

Companhia de Desenvolvimento Habitacional e Urbano
CDHU

Authors, Partners and Reviewers

Authors:

Conselho Brasileiro de Construção Sustentável (CBCS)

Brazilian Sustainable Construction Council

Prof. Dr. Vanderley Moacyr John (Prof. Poli-USP and CBCS advisor)
Msc. Diana Csillag (Director, CBCS)
Dr. Marcelo Vespoli Takaoka (President of the Council, CBCS)
Dra. Vanessa M. Taborianski Bessa (CBCS Researcher)
Msc. Eliane Hayashi Suzuki (CBCS Researcher)

Partners:

Companhia de Desenvolvimento Habitacional e Urbano (CDHU) e Secretaria da Habitação do Estado de São Paulo

Housing and Urban Development Agency (CDHU) and Housing Secretariat of the State of São Paulo

Lair Krahenbuhl (CDHU President and Housing Secretary of the State of São Paulo)
Gil Scatena (Advisor of the Chief of Cabinet of the Housing Secretariat)
Leonardo MacDowell de Figueiredo (Member of CDHU Qualihab - Programa da Qualidade da Construção Habitacional do Estado de São Paulo – Programme for Quality of Housing Construction of the State of São Paulo)
Eduardo Baldacci (Energy efficiency manager, CDHU)
Eduardo Trani (Chief of Cabinet of the Housing Secretariat)
Altamir Tedeschi (Expert, rational use of water projects, CDHU)
Ana Maria Antunes Coelho (Expert, landscaping projects, CDHU)
Arnaldo Rentes (Expert, landscaping projects, CDHU)
Fábio Leme (Member of CDHU Qualihab)
Irene Rizzo (Project Manager, CDHU)
João Luiz F. Neves (Expert, energy efficiency projects, CDHU)
Rafael Pileggi (Member of CDHU Qualihab)
Sandra Pinheiro Mendonça (Superintendent, Social Development, CDHU)
Stella Bilenjiam (Expert, energy efficiency projects, CDHU)
Valentina Denizo (Expert, Secretarias do Estado dos Negócios Metropolitanos e do Meio Ambiente - State Secretariats of Metropolitan Businesses and Environment and CDHU)
Viviane Frost (Superintendent, Urban Recovery Actions, CDHU)
Wandenir Dominiqueli (Expert, projects, CDHU)

Caixa Econômica Federal - Federal Economic Bank

Mara Motta Alvim (Operational Manager, National Department of the Environment)

Universidade de São Paulo - University of São Paulo (USP)

Prof. Dra. Lucia Helena de Oliveira (Prof. Politécnico-USP)
Prof. Dr. Orestes Marracine Gonçalves (Prof. Politécnico-USP and CBCS advisor)

Unicamp - University of Campinas

Prof. Dra. Marina Ilha (Prof. Unicamp)

Universidade Federal de Santa Catarina - Federal University of Santa Catarina

Prof. Dr. Roberto Lamberts (Prof. UFSC and CBCS advisor)

Consultants:
Msc. Maria Andrea Triana
Msc. Carla Sautchuk
Fábio Feldman Consultores

Reviewers:
UNEP- United Nations Environment Programme

Tatiana de Feraudy
Marina Bortoletti

Translators:
Andrew Melim
Jente Minne
Robert Bain

Designers:

Thad Mermer
Jente Minne

Executive summary

The United Nations Environment Programme (UNEP) launched in 2009 the SUSHI project (Sustainable Social Housing Initiative), which aims at providing guidelines for the inclusion of sustainable features in social housing projects.

The SUSHI project, through pilot projects implemented in Brazil and in Thailand, sought to identify, define and assess essential sustainable solutions that could be incorporated in the design process and construction of social housing projects. This assessment was conducted considering all the stakeholders involved in this process: consumers, suppliers, and especially project developers.

The construction sector experiences a rapidly rising demand, due namely to the rapid urbanization and population growth, especially in developing countries. Considering that the building sector is one of the most important contributors to the emission of greenhouse gases, the study of sustainable construction solutions is becoming increasingly relevant.

Taking these factors into account, UNEP chose the city of São Paulo, in Brazil, as one of the two strategic locations for the development of a pilot project for promotion of sustainable technologies and strategies in social housing projects. The objective of the project is that the results and lessons from this project can build the basis for replication of this sustainability approach in other regions with similar characteristics, or the adaptation of the approach in divers regions.

During the course of this project, the Brazilian team, led by the Brazilian Council for Sustainable Construction-CBCS (Conselho Brasileiro de Construção Sustentável) developed:

1. An assessment, in the form of a case study, of the state of social housing in the State of São Paulo, including an analysis of the concept of sustainability applied to this assessment and an identification of items that should be adressed to develop a proposal for sustainable initiatives. Results of this study were compiled in the report titled "Mapping of the key stakeholders and processes affecting the selection of solutions (technologies and materials) for social housing projects".
2. An assessment of previous initiatives conducted by CDHU that aimed at integrating sustainable elements in social housing projects. This assessment covered several initiatives, that tested alternatives in the project design, supply of appliances, or provision of alternate sources of water supply/heating, among others.
3. A compilation of the results of the two reports mentioned above, which led to the preparation of this report. This study emphasizes the analysis of technologies and alternatives in housing construction projects that could be applied to social housing projects in São Paulo. The report provides an analysis of costs and benefits, as well as efficiency of the alternative solutions selected to improve the sustainability performance of social housing units.

Although sustainable construction encompasses the study of several sustainability techniques and natural resources, the SUSHI project in Brazil decided to give priority, as the project scope, to the themes of water and energy. In this context, in the area of "water", the experts chose to work on sustainable options for rational use of water and demand management in social housing. In the "energy" area, solutions for improvement of thermal and visual comfort, increase in the use of renewable energy, provision of alternative water heating sources (namely solar heating) and solutions for the reduction of air-condicioning use were assessed.

This report is divided in three parts. The first chapter presents sustainable solutions that relate to water and energy resources, are available on the market, and can be applied to social housing projects.

Selected solutions for energy efficiency include design solutions (e.g. standardization of ceiling height, orientation), alternate materials (lining and low-absorptance glazing, frames, windows and shading devices to affect the thermal load of the building, natural shading), renewable energy sources (solar heating systems, photovoltaic energy), and solutions for the operation of buildings (efficient appliances, remote and individual metering of energy and water inputs). Solutions to improve water use efficiency include alternative water supply sources (rainwater harvesting, water reuse through phytotreatment, or in-situ sewage treatment), water management solutions (individual consumption metering, use of water-saving appliances) and land-use solutions (permeable pavement, e.g. hydraulic macadam).

This report also surveys other important items for building systems, related to thermal comfort and energy efficiency, based on reference to national norms and previous experiences of consultants in these areas. As examples, we can cite: the adequacy of the project to bioclimatic zones established by Brazilian norm ABNT NBR 15220 (concerning thermal performance), the study of materials quality, the interference of surroundings and of the climate on the building, the management of supply and demand of energy and the quality of installation of building systems in comformity with the ABNT NBR 15575 norm, which related to performance of residential buildings of up to five floors.

For building systems related to water use, the report highlights aspects of reliability, quality and maintenance of sanitary equipment and hydraulic materials, as well as aspects of water quality and health, management of water demand and supply, load generated by the building on rainwater drainage and local sewage infrastructure, and the interference of the building on aquifers.

The second part of this report provides the technical evaluation of the solutions presented in the first part. The third part provides recommendations, based on this technical evaluation, which can be useful to the entrepreneur when choosing the most appropriate sustainable technology.

For each solution, costs and benefits were considered to allow project developers to analyse the solutions considering the life cycle of the building. The classification of solutions on a performance scale aims at facilitating the evaluation and the selection process for technologies. The recommendations also include preliminary guidelines for the entrepreneur to identify the types of solutions available on the market and understand the impact that each type of technology will have, as well as the relative cost of one solution compared to the other.

The recommendations presented can be applied by project managers and developers as well as adapted to regional or local cultural, social and economic characteristics of the project. The developed guidelines will be implemented and tested with SUSHI project partners in the upcoming years, taking into account the results of a post-occupancy evaluation, to better define the viability of solutions especially through the approval of the final user.

List of abbreviations and acronyms

ABNT	Associação Brasileira de Normas Técnicas Brazilian Association of Technical Norms
ART	Anotação de Responsabilidade Técnica Technical Responsibility Rating
CATE	Centro de Aplicação de Tecnologias Eficientes Centre for Application of Efficient Technologies
CBCS	Conselho Brasileiro de Construção Sustentável Brazilian Council for Sustainable Construction
CDHU	Companhia de Desenvolvimento Habitacional e Urbano Housing and Urban Development Agency
CONAMA	Conselho Nacional do Meio Ambiente Brazilian National Environment Council
CONPET	Programa Nacional de Racionalização do Uso de Derivados do Petróleo e do Gás Natural National Programme for Rational Use of Oil and Natural Gas Products
CREA	Conselho Regional de Engenharia, Arquitetura e Agronomia Regional Engineering, Architecture and Agronomy Council
DAEE	Departamento de Água e Esgoto Water and Sewage Department
EPS	Expanded polystyrene (poliestireno expandido)
INMETRO	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial National Metrology, Standardization and Industrial Quality Institute
RTQ-R MME	Ministério de Minas e Energia Mines and Energy Ministry
TV PBE	Programa Brasileiro de Energia Brazilian Energy Programme
PBQP-H	Programa Brasileiro de Qualidade e Produtividade do Habitat Brazilian Programme for Housing Quality and Productivity
PLC	Power Line Communication
UNEP	United Nations Environment Programme
PSQ	Programa Setorial da Qualidade Sectoral Quality Programme
PROCEL	Programa Nacional de Conservação de Energia Elétrica National Electrical Energy Conservation Programme
QUALINSTAL-GÁS	Programa de Qualificação de Fornecedores de Instalações Internas de Gases Combustíveis e Aparelhos a Gás Programme for Qualification of Suppliers of Internal Equipments of Combustible Gases and Gas Appliances.
QUALISOL	Programa de Qualificação de Fornecedores de Sistemas de Aquecimento Solar Programme for Qualification of Suppliers of Solar Heating Systems
SAS	Regulamento Técnico da Qualidade para o Nível de Eficiência Energética de Edificações Residenciais Technical Quality Regulation for the Energy Efficiency Level of Residential Buildings

Contents

Introduction

UNEP, in the context of its sustainable buildings and construction activities, has developed a project for sustainable construction focused on social housing programmes in developing countries. This project is called SUSHI (Sustainable Social Housing Initiative).

The SUSHI project recognizes the interaction between social housing units and the urban environment. The objective of the project is to develop principles and guidelines specifically designed for social housing programmes, to achieve housing units that have an improved social, economic and environmental performance. Therefore, although the project focuses especially on energy and water efficiency, it also considers the buildings' cost-efficiency, comfort level, durability, ease of maintenance, impact on health, and connection to local culture.

The strategy developed through the SUSHI project aims at establishing a new approach with partners and highlight opportunities for new social housing models to the building and construction sector. This multi-stakeholder approach allows to identify potential benefits for the economy (business opportunities, "green" jobs), the government (reduced healthcare costs, workers' productivity, children's learning abilities), the society (wealth generation, pollution reduction), financial agents (new financing opportunities, better guarantees, reduced risk of premature obsolescence of the building) and last but not least for the final user, the families that will live in buildings that provide a higher quality of life.

In Brazil, the project was implemented in a period where new solutions were searched for. Even after the 2009 economic crisis, the real estate market was constantly growing in the country. Social housing units represent an important part of this market, especially after the governmental decision to build 1 million housing units in two years (2010-2011).

Facing this context, the Brazilian team of the SUSHI project created a network of partners to discuss the sustainability aspects of social housing in Brazil, and develop an approach to apply and disseminate these concepts in projects that would better respond to the needs and well-being of families.

Besides the partnership between UNEP and CBCS, the project brought together institutions that have renowned experience in social housing, energy efficiency, thermal comfort and rational water use, such as the Caixa Econômica Federal (the national housing bank), the Housing and Urban Development Agency of the State of São Paulo (CDHU), the Polytechnic School of the University of São Paulo (Escola Politécnica da Universidade de São Paulo-USP), the Federal University of the State of Santa Catarina (Universidade Federal de Santa Catarina-UFSC), the State University of Campinas (Universidade Estadual de Campinas- Unicamp) and a consulting group: Fábio Feldmann Consultores.

The team produced several deliverables during the project. A first assessment of the state of play of social housing in Brazil and opportunities for inclusion of sustainable features was produced, titled "Mapping of key stakeholders and processes affecting the selection of solutions (technologies and materials) in social housing projects". Upon request of CDHU, the team also conducted a survey of previous initiatives undertaken by the agency to incorporate sustainable features in social housing projects. Results were published in the second report of this series, titled "Lessons Learned: Solutions for Sustainability in Social Housing with the Housing and Urban Development Agency of the State of São Paulo (CDHU)".

This report is the third component of this series presenting opportunities for integration of sustainable solutions in social housing projects. It presents guidelines and recommendations to integrate sustainability solutions in social housing in Brazil. The actions proposed in this report are based on research on consultation with different partners involved in the project, on the results of the survey of previous CDHU experiences, and on contributions from specialized consultants, with expertise in the areas of energy efficiency, thermal comfort, and rational water use.

The first chapter describes sustainability actions related to energy efficiency and rational use of water. This chapter is followed by a chapter focusing on the requirements for succesful inclusion of such actions in building systems, through consideration of quality and durability of selected solutions.

Based on the survey of available solutions and actions, these were evaluated at the technical level to verify parameters for inclusion of these solutions in the stages of design, construction and operation/maintenance of the building. Risks associated with the implementation were also considered. The third chapter pesents twenty-two tables detailing solutions for improved energy efficiency and rational use of water, specifying the required actions, the level of difficulty for implementation and the availability of suppliers for each of the stages of the building life-cycle. These characteristics were rated according to the technical viability of the solution as high/medium/low (e.g. low implementation difficulty, medium availability of suppliers, high impact).

The last chapter defines an “itinerary”, or “agenda”, for social housing programmes, based on the sustainability actions presented, through two tables aimed at facilitating the selection process for sustainable solutions/ technologies. These solutions were listed and assessed based on their installation and operation cost, their social, economic and environmental benefits, and their efficiency level. This assessment was conducted for a specific geographical region, and in a specific context, therefore it does not constitute an absolute ranking of solutions. However, it is aimed at providing guidance for assessment and selection of technologies, and can be adapted to the requirements and specifications of other housing projects.

1 A survey of sustainable solutions for social housing projects available on the brazilian market

In this chapter, a technical assessment of sustainable measures for social housing is conducted. The sustainability measures surveyed in the Lessons Learned Report with the Company of Housing and Urban Development of São Paulo (CDHU), and available on the Brazilian market, are summarized.

After this review, the performance requirements for these solutions and the factors influencing their implementation are presented in Chapter 2. Chapter 3 presents the cross-evaluation of the identified solutions, based on the technical evaluation in this chapter and the requirements identified in Chapter 2.

1.1 Energy

In terms of energy, sustainability can imply the following: use of renewable energy, more efficient appliances and strategies to reduce energy demand and/or minimize its long term increase.

Energy consumption in the Brazilian residential sector is divided as shown in Figure 1 – Share of appliances in the energy consumption in the Brazilian residential sector (source: Eletrobrás, 2007).

The most significant consumption areas correspond to showers (water heating), refrigerators, heating, ventilation and air conditioning (HVAC) and lighting.

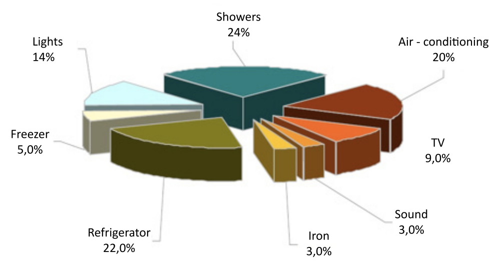


Figure 1 – Share of appliances in the energy consumption in the Brazilian residential sector
(source: Eletrobrás, 2007)

1.1.1 Solar water heating

O aquecimento de água é responsável por uma fração Water heating is responsible for 20% (GHISI; GOSCH; LAMBERTS, 2007) to 24% (ELETROBRÁS, 2007) of the consumption of residential electricity. However, the rate of consumption varies significantly according to climatic regions (Ghisi, Gosch and Lamberts, 2007). Therefore, changes in the source of energy for water heating as a strategy to promote sustainability is especially relevant in the regions of the Midwest, South and Southeast, where water heating is responsible for a great share of electricity consumption. In the North and Northeast regions, energy consumption for water heating is respectively only 2% and 8 % of the total demand (ELETROBRÁS, 2007).

According to ABNT NBR 15569 (2008), a solar heating system is composed of a collector, a thermal reservoir, an auxiliary heating system, accessories and their hydraulic interconnections.

The economic and environmental benefits of a solar heating system, both for electrical utilities companies and users are shown by research (NASPOLINI; MILITÃO; RÜTHER, 2010). However, they depend on the intensity of use – associated with climate, personal habits, efficiency, the environmental impact of energy used by auxiliary heating systems and the amount of cold water wasted awaiting the arrival of hot water (in case of buildings not equipped with a hot water closed loop system).

A common solution for auxiliary heating involves the use of internal thermal resistances in the hot water tank, which can be turned on manually (resulting in the lack of hot water at certain times) or by automatic thermostats and timers. Equipment with automatic timers is rare in Brazil, so in some situations the solar system has an electrical consumption rate higher than a conventional shower. Recently, electric showers with manual or automatic adjustment of the temperature were introduced. This system consumes less electricity, but its environmental benefits in reducing periods of peak demand are still unknown. The use of solar systems may be efficient in social housing projects, considering the limitations mentioned previously, and taking into consideration the relative importance of water heating in the total energy consumption of the residential unit.

1.1.2 Photovoltaic Energy

Via the photovoltaic effect, the energy contained in sunlight can be converted directly to electric power. The photovoltaic effect is obtained through very thin foils of semiconductor materials such as silicon. The sun-rays bounce off the surface of the photovoltaic panel and a flux of electrical energy is created which causes the operation of electrical equipment connected to the solar panel.

Besides saving energy, photovoltaic systems aim at providing electricity in remote locations, far from the electrical grid, or by the cogeneration of electricity, diminish the amount of energy supplied by the utility company.

Photovoltaic energy has been adopted in isolated communities of Brazil, replacing diesel generators, but it is not yet a fully economically viable solution without important subsidies (MARTINS; BAZZO; RÜTHER, 2005), particularly for low-income families who rely heavily on subsidized energy (low energy bills).

The integration of photovoltaic systems connected to the electrical grid in higher income households, who pay the full electricity price, has been defended by experts (RÜTHER; ZILLES, n.d.). The use of photovoltaic energy in social housing projects requires a detailed cost-benefit analysis showing the return on investment and the economic viability of the project in relation to environmental benefits.

1.1.3 Energy-efficient equipment and appliances

This strategy consists in the use of equipment and domestic appliances with proven energy efficiency, which in the case of Brazil, can be done through the Brazilian Labeling Program (PBE) and Seals PROCEL and CONPET.

According to (ELETROBRÁS, 2007) lighting is responsible for 14% of residential electrical consumption; refrigerators 22% and air conditioning 20%.

Equipment that can be easily included in the construction of and applicable to social housing projects, because of their low cost of installation and maintenance, are ceiling fans, an alternative to reduce the increasing demand for air conditioning (GHISI, GOSCH; LAMBERTS, 2007); and compact fluorescent lights.

Other home appliances such as refrigerators are not usually part of a housing project and, as the experience in CDHU shows, their introduction or replacement must be made considering the needs and demands of each household.

1.1.4 Measures of passive thermal comfort

HVAC systems represent between 11 and 40% of residential electrical consumption in Brazil, and this percentage has been growing due to an increased number of air conditioning units (GHISI; GOSCH; LAMBERTS, 2007).

The introduction of passive comfort measures can minimize this trend and generate important economic and environmental benefits.

1.1.4.1 Implementation of high ceilings

Ceiling height is an architectural feature that directly influences room temperatures due to the thermal gradience, a physical property which causes warm air to be naturally stored in the upper part of the room and cold air at the bottom. Rooms with higher ceilings keep the warmer air up and away from the inhabitants.

The ABNT NBR 15575 performance standard for buildings of up to five floors stipulates a minimum ceiling height of 2.20 m for bathrooms and 2.50 m for all other areas of the residential unit, observing the relevant legislation. CDHU uses a ceiling height of 2.60 m, the minimum height allowed by the Construction Codes of most cities. The increased height of ceilings could improve temperature comfort ranges inside social housing units at a reasonable cost.

However, for this strategy to deliver the expected effect, other architectural features must be considered in the design phase and combined to the modification of ceiling height, in order to improve internal air circulation, insulate the living space, and provide adequate solar orientation.

1.1.4.2 Ceiling Lining

According to Lamberts and Triana (2005), lined ceilings are required to ensure a minimum thermal performance and should be a basic requirement for approval of social housing projects. About 70% of the heat charge originates from the roof and 30% from the front of the building (CAVALCANTI; PRADO, 2001)

Lined ceilings create an insulating layer of warm air, which separates the dweller from the heat radiated through the roof during the day, and reduces heat loss at night.

The liner can be of different materials such as plaster, wood or PVC. The lining can also be a concrete slab, consisting of coated, reinforced concrete filled with cast ceramic blocks or EPS blocks.

The use of insulating lining in social housing units may be an adaptable measure with a careful selection of the type and cost of material, its performance, and its potential impact according to the climatic region.

1.1.4.3 Coatings of low absorbance

This action requires the use of paints with low absorbance, typically associated with bright colors. Brazilian standards specify the properties of coverage according to absorbance, which is the quotient of the rate of absorbance of solar radiation in a surface by rate of incidence of solar radiation on the same surface (ABNT NBR 15220-1). Krüger e Lamberts (2000) found a reduction of up to 3.8 K of the indoor temperature with daytime ventilation and 6 K with night-time ventilation directly related to white paint on the roof, thus, a low coefficient of solar absorption.

According to Cavalcanti and Prado (2001), single-family homes represent the majority of social housing as compared to multifamily units. Therefore, the roof is the architectural component most exposed to climatic variations. According to the Data Processing Company of São Paulo Companhia de Processamento de Dados do Estado de São Paulo (PRODESP), up until December 2010, 38.7% of the buildings delivered by CDHU were multi-family housing, while 61.3% were of single-families[1]
.

The choice of roof coating can be associated with climate, availability of materials, durability and need for acoustic treatment, especially in metallic roofing.

Attention must be paid to the maintenance and cleaning of the coating covers. The loss of solar reflectance of metallic paint coating was 6% in a period of 1.63 years, according to Cheng et al (2011). This implies that for a longer period of time, the loss will be proportionately greater and change the insulating properties of the coverage material. Solar radiation reflectance is the quotient of long wave radiation reflected divided by the long wave radiation on the same surface (ABNT NBR 15220).

Therefore, we recommend the use of low absorbance coatings and high reflectance covers, that is, metallic material (if properly insulated thermally), or bright or metallic paint, choose the most appropriate solution according to cost and performance.

1.1.4.4 Frames and shading

According to Lamberts and Triana (2005), windows are the main elements influencing the thermal performance of a dwelling, and one that requires the least technological developments in all sectors and income levels across Brazil.

Windows must respond effectively to the different climatic requirements in the country, being weather-tight in cold climates and allowing for adequate ventilation and shading in hot climates.

Of all the parts that make up a window, particular attention should be paid to the blinds. The shading effects produced by windows represent a major improvement in thermal performance, especially when windows are built in light colors.

The standard window in Brazilian social housing projects is a sliding window, which reduces the effective area of ventilation to 50%.

In theory, an increase in the size of a window increases thermal comfort. Krüger and Lamberts carried out a simulation in 2000 for the city of Florianópolis (latitude 27,5) in the summer month of January, by doubling the area of the window and therefore switching effective aperture from 50% to 100%. There was no significant improvement in thermal comfort: increased rates of airflow did not decrease the temperature inside the apartments. In this scenario however, the effective use of natural lighting can decreases the consumption of electricity used for lighting.

Developers of social housing units need to have the flexibility to choose between different windows designs in the planning stage, without having to select the same type of window for different projects in different weather zones.

Figure 2 – Example of sliding windows in social housing units

1 In: http://www.prodesp.sp.gov.br/

1.1.4.5 Natural shading

Natural shading consists in the creation of natural screens instead of artificial ones, such as metal awnings. Shading cuts down the incidence of solar rays on the ground and on vehicles and thus helps reducing heat island effects. Natural shade can be achieved by planting fruit trees, shrubs and climbing plants, provided their roots do not damage the pavement.

The areas covered by vegetation have lower temperatures and higher humidity. Besides lowering temperature by shading directly, vegetation reduces solar heat gain due to evapotranspiration (BARBOSA; AMO; LABAKI, 2010). This measure offers simplicity and low cost, and can be applied in social housing projects, considering the specific requirements of the land (available space) and region (preferring local species).

1.2 Rational use of water

Sustainable measures for the rational use of water, which could be applied to social housing projects, are presented below.

1.2.1 Individualized water comsumption meters

Individualized water meters provide the water consumption per housing unit in the vertical and horizontal condominiums. The water bill can be then established, for each unit, in view of the actual consumption recorded by respective water meters, plus a pro-rated portion of the water consumption to meet the common needs of the building (DOMINIQUELI, 2007).

For state sanitation companies, the practice of individualized measurement of water consumption emerged, based on market demand. The objective was to encourage rational water use, but especially allow users to manage their individual consumption and pay for what they actually consume. In this manner, the utility provider has a direct role and responsibility in ensuring timely payment of utilities, and deals with individual households.

This form of measurement may be an interesting solution for multifamily social housing units, but the main impact will be to raise awareness of consumption. It may not have an economic impact or lead to a consumption decrease, considering the low price of water.

1.2.2 Remote metering

Referred to as telemetry or remote metering of utilities, it is the automation of consumption readings and the transmission of this data from the residential sources to the processing station. Technologies for remote measurement of residential utilities available on the market are: Radio Frequency, PLC, and the network of land and cellular telephone lines, cable TV, satellite, and hybrid systems (ROZAS; PRADO, 2002).

In addition to ensuring safety because the technicians do not need to enter in the buildings to make meter readings, remote measurement provides real-time consumption data and allows identifying leaks in real time, thus avoiding waste of water and additional costs for the residents of social housing units.

1.2.3 Rainwater harvesting

The main goal of this measure is the reduction of supply of potable water from utility companies by collecting and treating rainwater for non-potable purposes.

The process consists of collecting rainwater from impermeable areas (roofs mainly), treating and accumulating the water in storage tanks for subsequent use. The use of rainwater in the residential sector would be more efficient if combined with the reuse of water (grey-water). This measure can deliver savings of up to 36% in potable water consumption, if non-potable water is used for toilets, irrigation of gardens and floor washing. However, the investment payback period of this measure is estimated at 17 years, due to the low cost applied to water carriers in Brazil (GHISI; OLIVEIRA, 2007), which leads to believe that it is not ideal in social housing programmes.

1.2.4 Water saving equipment

This measure consists in using sanitary devices and equipment that use less water for their operation, compared to conventional equipment. Examples are mechanical valves, flow regulators and restrictors, sanitary basins of reduced volume, valves and double-flush discharge buttons.

In Belo Horizonte, some of these devices were installed in low-income houses (families earning up to three minimum wages), inclusing as self-closing faucets, adjustable discharge valves, and flow rate regulators for faucets and flushing tanks. A reduction of 7.5% in water consumption was achieved, a considerable result according to the authors of the research (VIMIEIRO; PADUA, 2005). The implementation may have a positive environmental and economic impact and should be made in collaboration with the user.

1.2.5 Phytotreatment

Filtering Soils or Wetlands are systems that make use of the filtering characteristics of a terrain especially prepared to treat domestic sewage (OLIVEIRA et al., 2005).

The process of decontamination of water for reuse becomes more efficient when vegetation such as mangrove or marsh plants is planted on the terrains where effluents are to be treated. Oliveira et al. (2005) highlight that this system has the advantage of saving electricity, as it is a natural process. Another advantage is the infiltration of rain water into the filtering ditch.

The performance of treatment is generally high and enables the reuse of water to flush toilets, irrigate gardens and wash floors. However, in the case of remote or isolated housing units, it is restrictive due to the small area of the lots.

1.2.6 On-site sewage treatment

Sewage treatment in situ is provided by compact stations or septic tanks with anaerobic filters that handle sewage on the location where it is generated. For the application of this solution in social housing, the location of the units and the required maintenance by the dwellers has to be considered carefully.

1.2.7 Permeable pavement

Permeable pavements are simple systems of infiltration, where water runoff is diverted through a permeable surface to the interior of the soil structure during the infiltration process. This is aimed at reducing the water flow drained at the surface and can improve water quality, contributing to the increased recharge of groundwater. The limitations are the high cost of implementation and the need for maintenance, which could be offset by the benefits generated (ARAÚJO; TUCCI; GOLDENFUM, 2000). However the high initial cost constitutes an important limit for application in social housing. Examples of this technology are hydraulic tarmacadam, interlocked blocks and "gramacadame".

- Hydraulic tarmac/ asphalt
  This asphalt is made of aggregated gravel of variable diameters, compressed, with particles firmly integrated in each other and voids filled with cushioning material such as rock dust or sand, with the help of water. The stability of this layer is obtained from the dynamic mechanical action of compression.

- Interlocked Blocks
  This pavement is made of pre-cast concrete blocks and it is a modern, enhanced version of cobblestone pavement.

- "Gramacadame"
  This asphalt is similar to hydraulic tarmac in its components and assembly. The difference is a more uneven matrix of the aggregates, with larger voids and the absence of the filler, the rock dust paste and water that fills the voids in the hydraulic tarmacadam. The filler is substituted by agricultural substrata that loosely fill the stone matrix and preserves an amount of its porosity to water and air. Grass turf are planted on top of the pavement.

2 Performance requirements for sustainable solutions

The objective of this section is to present the performance requirements for a number of potential sustainability measures, selected based on regulations, referenced literature and materials available on the market. Measures for thermal comfort and energy efficiency have different requirements according to the bioclimatic zone. The performance requirements for sustainable measures in the areas of thermal comfort, energy efficiency and conservation of water are presented below.

2.1 Building systems for thermal comfort and energy efficiency

The performance requirements for energy conservation measures have been detailed in two sections, that relate to (1) measures designed to improve thermal comfort and (2) measures to improve energy efficiency. These measures have environmental, social and economic justifications.

The sustainability measures and technologies described aim at having a positive environmental impact, as well as provide a comfortable environment that is adapted to the user's needs. These measures reduce or eliminate the energy demand from mechanical ventilation and airconditioning systems and contribute to better management of energy demand. Measures linked to increasing supply of energy from renewable sources and providing alternatives to conventional electric energy production are also considered.

The social dimension of these measures relates to the objective of providing an adequate level of comfort in the housing unit, and providing an efficient and stable access to energy for the user. The user is the key focus on these measures as the dweller is responsible for operating and maintaining the building systems, as stipulated in the design phase.

The user is also targetted as a beneficiary of the measures, in their economic dimension. Building projects should be cost-efficient and provide opportunities to save costs in energy bills and in maintenance activities. At the same time, the country as a whole can benefit from these environmental sustainability measures through reduction of energy consumption (and therefore energy dependency) and cost savings. The studies developed through the SUSHI project can help political decision making. The performance requirements for energy use measures can be classified as:

Performance requirements for improvement of thermal comfort:

- Appropriate site selection and building design according to the location (strategies);
- Building systems (quality and construction properties of materials and architectural components);
- Impact of the surroundings and local climate on the building.

Performance requirements for energy efficiency improvement:

- Demand management (technologies that reduce energy consumption);
- Supply management (renewable enegy);
- Quality in installation, maintenance and operation of building systems for energy efficiency.

More specific requirements for each of these items are outlined below.

2.1.1 Performance requirements for thermal comfort.

2.1.1.1 Appropriate design and construction of the building according to the site: standards and classification

The NBR 15220-3 norm (ABNT, 2005) provides information on brazilian bioclimatic zones, classifing 330 cities in eight bioclimatic zones according to their type of climate.

The distribution of the zones was made according to parameters such as temperature, humidity and altitude of the cities. For cities that are not specifically identified in the standard, the climate should be assessed based on the nearest cities with similar characteristics. Specific strategies for improvement of thermal comfort have to be developed according to the climate zone.

Zone 1 (Z1) refers to the coldest climates in the south of the country, which experience colder winters and where there is a greater need for heating in the cold season. Zones 2 and 3, predominantly in the south and south-east respectively, experience pronounced summers and winters. Zones 4, 5 and 6 also require different between strategies for summer and winter, although seasonal changes are much less pronounced. In Zone 4, passive solar heating is considered important even in winter, while in Zones 5 and 6 this strategy is not recommended. Zones 7 and 8, in the Northeast and North of the country require strategies for a permanent summer throughout the year. (LAMBERTS; TRIANA, apud JOHN et al, 2010).

In the case of the State of São Paulo, the cities are located within bioclimatic zones 2, 3, 4, 5 and 6. As such, project criteria should be established based on the bioclimatic zone where the social housing project will be located. In this sense, NBR 15220-3 (ABNT, 2005) establishes specific project strategies appropriate for summer and winter for each bioclimatic zone and, for single-family social housing units, also establishes performance requirements for the construction components (walls, roof, windows and doors).

For multi-family buildings, the criteria for comfort in summer and winter, as well as the characteristics of construction materials, are defined by NBR 15575 (ABNT, 2008) – Standard for the performance of buildings with up to five stories. For walls and roofs, criteria for thermal performance are established to address conductivity and thermal capacity of the materials (taking into consideration all of its layers, namely, the type of tile or insulation). For windows and doors, it establishes the need for shading and the percentage of openings required for ventilation.

Table 1 shows a summary of the requirements of NBR 15575 (ABNT, 2008) for multi-family buildings in different bioclimatic zones.

In November 2010, the Energy Efficiency for Residential Buildings Label was launched (INMETRO). The label classifies buildings on a scale from E to A, with A being the most efficient. It builds on Standard NBR 15575 (ABNT, 2008), establishing prescriptive criteria and simulation methods to verify the climatic suitability of the building. In this way, the premises for the project, as well as the choice of strategy and of materials, should be in agreement with these criteria. The CAIXA's Selo Casa Azul (JOHN et al, 2010) also establishes criteria for the evaluation of projects according to the comfort level provided, using the bases defined in NBR 15575 (ABNT, 2008).

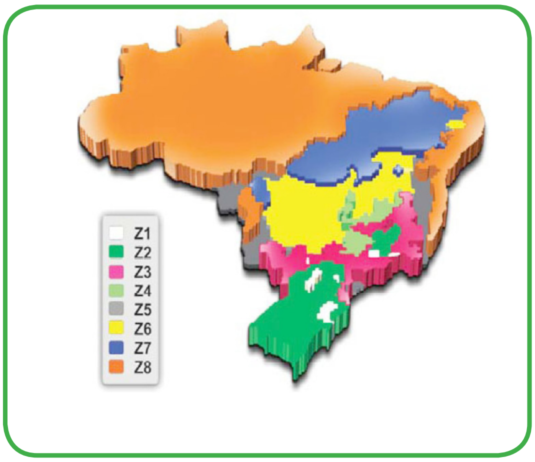


Figure 3 – Bioclimatic zones proposed by ABNT NBR 15220-3 (Source: JOHN et al, 2010)

Table 1 – Requirements of NBR 15575 (ABNT, 2008) for different Brazilian bioclimatic zones.

Zone	15575 Strategies		Openings for ventilation * (A in % of floor area)	Shading of the openings	External walls		Roof	
	Summer	Winter			U min	CT min	U	α
1	-	(a) Building solar heating / (b) Heavy internal sealing (thermal inertia)	A ≥ 8% Medium openings	Allow sun during winter	≤ 2,50 (light wall)	≥ 130	≤ 2,30	-
2	(a) Cross ventilation	(a) Building solar heating / (b) Heavy internal sealing (thermal inertia)	A ≥ 8% Medium openings	Allow sun during winter	≤ 2,50 (light wall)	≥ 130	≤ 2,30	-
3	(a) Cross ventilation	(a) Building solar heating / (b) Heavy internal sealing (thermal inertia)	A ≥ 8% Medium openings	Allow sun during winter	≤ 3,70 e α < 0,60	≥ 130	≤ 2,30	α ≤ 0,6
					≤ 2,50 e α ≥ 0,60		≤ 1,50	α > 0,6
4	(a) Evaporative cooling and thermal mass for cooling / (b) Selective ventilation (for periods when internal temperatures exceed those outside)	(a) Building solar heating / (b) Heavy internal sealing (thermal inertia)	A ≥ 8% Medium openings	Shade openings	≤ 3,70 e α < 0,60	≥ 130	≤ 2,30	α ≤ 0,6
					≤ 2,50 e α ≥ 0,60		≤ 1,50	α > 0,6
5	(a) Cross ventilation	(a) Heavy internal sealing (thermal inertia)	A ≥ 8% Medium openings	Shade openings	≤ 3,70 e α < 0,60	≥ 130	≤ 2,30	α ≤ 0,6
					≤ 2,50 e α ≥ 0,60		≤ 1,50	α > 0,6
6	(a) Evaporative cooling and thermal mass for cooling / (b) Selective ventilation (for periods when internal temperatures exceed those outside)	(a) Heavy internal sealing (thermal inertia)	A ≥ 8% Medium openings	Shade openings	≤ 3,70 e α < 0,60	≥ 130	≤ 2,30	α ≤ 0,6
					≤ 2,50 e α ≥ 0,60		≤ 1,50	α > 0,6
7	(a) Evaporative cooling and thermal mass for cooling / (b) Selective ventilation (for periods when internal temperatures exceed those outside)	-	A ≥ 5% Small openings	Shade openings	≤ 3,70 e α < 0,60	≥ 130	≤ 2,30 FV	α ≤ 0,4
					≤ 2,50 e α ≥ 0,60		≤ 1,50 FV	α > 0,4
8	(a) Constant cross ventilation NB: Passive ventilation will not be sufficient during the hottest hours	-	A ≥ 15% Large openings	Shade openings	≤ 3,70 e α < 0,60	no requirement	≤ 2,30 FV	α ≤ 0,4
					≤ 2,50 e α ≥ 0,60		≤ 1,50 FV	α > 0,4

Symbols and units: Thermal conductivity – U: W/m2.K Absorbance-α Heat capacity: CT: kJ/(m²K) FV: Photovoltaic
NB:* In Zones 1 to 6, it should be possible to seal the ventilation areas during cold periods.

2.1.1.2 Building Systems

The building components have specific thermal performance properties and should be carefully installed, operated and maintained. To guarantee adequate performance, it is first of all necessary to observe the component's placing and orientation to verify whether the material will have the desired thermal performance. The manufacturer's recommendations when installing the components should be observed. The project developer should also ensure that the required maintenance will be conducted, and that users are informed, trained and able to adequately use the equipment.

Preference should be given to suppliers which participate in the Brazilian Program for Quality and Productivity (PBQP-Habitat), and technical catalogues should be consulted for provision of precise information on the correct installation and performance of the products.

The construction components (walls, roofs and openings) should be chosen according to their thermal and acoustic performance as well as their availability and the ease with which they can be replaced at the site.

Performance of walls and roofs

- Durability

In terms of durability, when choosing building components, attention should be paid to the installation specifications and local specificities, such as prevailing winds, solar irradiance, presence of acid rain, sea winds, etc. For example, roofing with metal tiles should be mounted in the opposite direction to prevailing winds to guarantee greater tightness, with attention given to the overlap required between one tile and another depending on their inclination. In locations where there is acid rain, the use of this type of tile is not recommended.

- Thermal performance

The first item to consider for walls is the required thermal capacity: a low thermal capacity leads to lower thermal inertia. The second item to consider is the necessity for thermal conductance: if walls are light, thermal conductance has to be higher, and it can be lower for heavier or more insulated walls. When selecting roofing solutions, the level of isolation required should be defined to verify which type of roofing material (tile, green roof), insulation material and radiant barriers should be used.

<u>Heat capacity</u>

Heat capacity (HC) is defined as the amount of heat required to cause a specific temperature change in a particular body. Walls and roofing with high heat capacity, and, therefore with high thermal inertia, should be restricted in regions with pronounced summers due to the thermal delay. They accumulate heat during the day and transfer it to the interior of the building at night, which is suitable for winter, but not for summer. For roofs, it is important to use thermal insulation to minimize the effect of environment overheating in summer due to direct solar irradiation during the day.

<u>Thermal conductivity</u>

To determine the overall thermal conductivity of walls and roofing, it is necessary to know the conductivity (W/m.K) and thickness for each layer of the component. The thermal resistance of air cavities, when they exist, is defined based on the direction of the heat transfer (horizontal for walls and vertical for roofing). NBR 15220-2 (ABNT, 2005) provides the calculations for conductance and heat capacity of roofing, while NBR 15220-3 (ABNT, 2005) and the Selo Casa Azul da Caixa (JOHN et al, 2010) provide some examples of the thermal properties of walls and roofing.

Besides the material, the colour also influences performance; for this reason, NBR 15575 (ABNT, 2008) determines the thermal conductivity depending on the absorbance of the walls and roofing. It advises the use of pale colours (low absorbance) in the vast majority of climates, since tropical summer climates are widespread in the country throughout most of the year.

<u>Thermal resistance</u>

The use of lining in the roof increases the thermal resistance of the roof, especially when combined with an air chamber, providing a more pleasant internal environment. Linings made from wood, plaster and PVC have a lower weight for the structure and a smaller heat capacity when compared to roof slabs (mixed or with EPS). Roof slabs facilitate the maintenance of systems that are below the roofing.

Radiant barriers can also be associated to walls or to the roof, made of materials such as aluminium blankets and stone wool, with the aim to increase the thermal resistance of components. The material's performance should be checked with suppliers through technical catalogues, as well as installation requirements. The performance of the radiant barriers depends on the thickness of the blanket and the presence of aluminium on one or both sides. Polyethylene foam provides low thermal conductivity, while aluminium provides low heat radiation, low absorbtion of radiative heat and high reflectivity.

Performance of windows and frames

For specification of the framing components, according to Ino et al. (2003), the external and internal factors contributing to the performance of the window and its adequacy with the user's requirements can be translated into four performance requirements: structural, use, tightness and durability.

Frames should be flexible and allow for climatic adaptation in order to respond to the ventilation, shading, rain protection and safety needs. With this in mind, the new Standard ABNT NBR 10821 - External frames for buildings - is being revised and will contain five parts: terminology, requirements and classification, testing methods, additional performance requirements (acoustic and thermal comfort) and installation and maintenance.

According to the interview of Eng. Fabiola Rago by AEC Web (2010), the main changes to the Standard are in Part 2 - Requirements and Classification. In this section, frames are classified depending on the building site, the number of floors of the building and the region of the country. There will be five categories in which the requirements for testing, safety and water tightness will be organized in a table to be identifiable by experts. For frames that are not installed in a vertical position, buildings that are not rectangular in form or even for buildings with specific requirements, the needs and the special requirements for use should be consulted in Standard ABNT NBR 6123- Forces due to wind on buildings- to determine the design pressure and the test pressure. The new standard will classify frames in three performance levels: minimum, intermediate and superior.

Besides the increase in durability that can result from avoiding the water penetration, tightness of the framing components is very important to allow greater control of heat gains and losses in the building.

To determine the ideal framing, it is necessary to think about the material that will be used, the need for openings for ventilation, lighting, and shading. Therefore, for materials like aluminium and PVC, frames should be of the correct size to minimize losses, verifying with the manufacturer the required dimensions to meet technical and financial requirements. For materials like timber, the choice depends on the supplier quality guarantee and on the ability to easily amend and work on the material.

The required openings (windows/doors) in relation to the floor area (as a percentage) and the need for shading can be determined according to the requirements specified by NBR 15575 (ABNT, 2008) and by RTQ-R (MME, 2010). Table 2 considers bioclimatic zones 2 to 6 present in the State of São Paulo in relation to the type of shading needed, openings for ventilation, lighting and other features of the frame according to criteria from these standards.

Operation and maintenance

Operation and maintenance should be conducted in the building with the aim of ensuring the performance of the systems and components as expected in the design phase. Items that facilitate maintenance should be considered in the design. User capacity building during project handover, in addition to providing user manuals, is crucial, as lack of maintenance or improper operation can affect the thermal performance of buildings.

SOURCE	Ventilation for living spaces	Kitchen ventilation	Bathroom ventilation	Lighting for living areas	Kitchen lighting	Bathroom lighting	Required shading	Other
NBR 15575	A ≥ 8	A ≥ 8					Shade openings and allow sunlight during winter for zones 2 and 3	
RTQ-R (level A)	A ≥ 8	A ≥ 8	A ≥ 10%	A ≥ 12.5%	A ≥ 12,5%	A ≥ 10%	Bonus for the use of special measures that favour ventilation with access to natural light (e.g. blinds)	Guarantee of nightime ventilation with protection against rain and security

Table 2 – Bioclimatic zones 2 to 6 present in the State of São Paulo.

2.1.1.3 Surroundings and climatic impact on the building

Natural shading can be used to lower the heat load of internal environments: the use of green roofs or vegetation in internal environments, as well as the use of vegetation in outdoor areas (e.g. parking lots and footpaths), are strategies that can minimize the heat island effect.

For effective natural shading it is important to consider the solar trajectory over the building site and surrounding areas in order to predict the required shading depending on the site and the microclimatic needs of the project.

When choosing vegetation types for natural shades, the plants' type, growth patterns (including seasonal modifications), dimension and shape should be considered to obtain the desired results. For instance, deciduous trees can be used in regions where heating is required in winter and shading is required in summer. When choosing to implement a green roof, it is important to assess the growth patterns of the plants or grass, as well as the maintenance needs, and the total weight of the system on the structure.

2.1.2 Performance requirements for energy efficiency

2.1.2.1 Demand management

Managing demand is a key strategy that allows to reduce consumption. Measures that simplify the reduction of housing energy demand can be considered. Efforts can be concentrated on equipment such as freezers, electric showers, lighting and airconditioning, which are the main end uses of brazilian households. It is necessary to combine the use of these efficient technologies with a change in behaviour of the user.

Demand management actions encompass measures that favor: the use of efficient equipment and household appliances; the use of alternative technologies for the water heating; a greater use of natural lighting and the use of energy-efficient artificial lighting systems; the selection of building systems that are suited to the local climate; and metering of energy use.

Use of efficient household appliances

The main performance requirement for the use of efficient equipment and appliances is that their degree of efficiency can be proven effectively. INMETRO's Brazilian Labelling Program (PBE) gives a classification of electric appliances depending on their energy consumption. Appliances concerned include airconditioning units, solar collectors, thermal storage tanks, freezers, light bulbs and lighting equipment, washing machines, motors, refrigerators, televisions, roof ventilators and photovoltaic panels. The programme also classifies equipments that run on gas and not electricity. Preference should be given to equipment and appliances that have achieved at least level A and preferably also comply with the PROCEL label (electricity equipments) or the CONPET label (gas equipments), which guarantee low energy consumption.

When energy efficient appliances are not provided, the entrepreneur should make sure that the future occupant or buyer are made aware, namely through "User Manuals", of importance and benefits of saving energy. Users should also receive information on relative operating costs of labelled equipment, to encourage demand for efficient appliances for individual or shared areas.

Figure 4 shows the energy savings that can be obtained with the use of some efficient equipment and appliances.

Figure 4 - Average energy savings obtained with PROCEL labeled appliances. Centre for the Application of Efficient Technologies (CATE). Source: Caixa (2010).

Eletrobrás, a company in the electrical energy sector controlled by the Brazilian government, provides every year a list of the equipment that was labelled through PROCEL. This list can be found (in Portuguese) at: http://www.eletrobras.com/elb/procel/main.asp.

Similarly, the CONPET website provides a yearly list with the equipment that was labeled during the year. This list is available (in Portuguese) at: www.conpet.gov.br.

The INMETRO website provides tables of consumption and energy efficiency level for all catalogued appliances and equipment. It can be found in Portuguese at: http://www.inmetro.gov.br/consumidor/tabelas.asp.

The user should check the efficiency level of the equipment that is being acquired/specified. When choosing electric or gas equipment bearing the INMETRO energy label, it is important to consider not only the voltage (110V or 220V) and the letter indicating the efficiency (ratings range from E to A, A being the most efficient) but also the energy consumption in kWh/month. The energy consumption can vary considerably depending on the type of equipment even when in the same energy efficiency level.

When appliances are provided with the housing unit, one of the main requirements is to promote options for greater personalization so that this measure is succesful. For example, establishing partnerships with suppliers will make it possible for the user to choose equipment more suited to their personal taste.

Use of alternative technologies for water heating

Efficient water heating systems as an alternative to the use of electric showers can be based on renewable energy, as is the case with solar water heating, or other systems such as natural gas or heat pumps. For these, it is important that the needs are evaluated depending on the building typology (single-family or multi-family buildings), the site, the possibility for installation with adequate performance, and the need for maintenance. In the case of multi-family buildings, the potential requirement for individual hot water metering and the system operating requirements should be carefully considered.

For each of installed systems, specific performance requirements should be observed. Solar water heating is the best option for climates that have ample sunshine throughout the year and, especially, for single-family residences. For multi-family housing, attention should be paid to existing design standards, the quality required for installation, and the distribution of the bill among users. Specific requirements due to local climate should be considered. Finally, it is important to have informtion on the different income categories of the families residing in the building. The chosen design should provide the most cost-effective alternative. In this specific case (water heating), the system's efficiency depends on the solar fraction attained.

For multi-family residences, natural gas systems can be used as an alternative to solar water heating, being more efficient when there is a natural gas network near the site. They can also be used as backup for solar water heating systems.

As performance requirements for natural gas systems, the following should be checked:

- Components: An instantaneous heater and a chimney (individual or collective) should be included to supply hot water only to the shower head in housing units.

- Efficiency of the equipment: Instant gas heaters should preferably have PBE level A or B. When using a hot water storage tank, it should be thermally insulated and of an adequate capacity. Heaters should be installed in locations permanently protected against bad weather and with adequate ventilation.

- Installation: When installating the system, preference should be given to installers who are part of the Qualification Program for Suppliers of Internal Gas Equipments and Gas Appliances– QUALINSTAL GÁS.

- Pipework insulation: The need for insulation of the pipes, depending on the distance between the equipment and the point of use, should be verified.

- Pipework size: The size of the pipes should be appropriate in case of provision of water to several locations simultaneously.

- Application of the relevant standards: Standards for the use of combustible gas in building systems:

  - NBR 14570 – Internal Installations for the Alternative Use of NG and LPG.

  - NBR 13103 –Suitability of housing environments for installation of natural gas appliances.

  - NBR 13523 – Building central of liquified petroleum gas (LPG).

  - NBR 13932 – Internal liquified petroleum gas (LPG) installations – Design and implementation

  - NBR 13933 – Internal natural gas (NG) installations– Design and implementation.

  - NBR 14024 – Building and industrial centrals for liquified petroleum gas (LPG) – bulk supply system.

  - COMPAGAS. Regulation for building gas installations. Available (in Portuguese) at: http:// www. compagas.com.br

Greater use of natural lighting and use of energy-efficient artificial lighting systems

Increasing the efficiency of lighting systems involves measures to increase the use of national lighting and measures to use more energy-efficient artificial lighting systems. To improve natural lighting of indoor environments, in both single-family and multi-family buildings, several items should be considered: façade area and openings, depth of internal spaces (area), required lighting to comform with regulations, and reflectance of internal walls. NBR 15575 (ABNT, 2008) establishes in its Part 1 general requirements for lighting performance, including minimum levels of natural lighting and minimum levels of artificial lighting.

For efficient artificial lighting the requirements outlined in the section on use of efficient appliances should be considered.

Metering energy input

Another important measure that should be considered in the management of energy demand is the metering of energy use; this can allow the user to better control their consumption and can result in a lower energy demand due to the impact of consumption reduction on energy bills. To achieve this, the metering systems should guarantee safe and automated end-use metering of the housing/building.

However the main factor determining the success of any measure to manage energy demand, independent of the system/technology adopted, is the user, both in terms of operation and maintenance of the technologies and in terms of awareness of the importance of energy conservation measures. In this sense it is very important that any measure be linked to educational and awareness raising initiatives. Energy use metering can serve this purpose.

2.1.2.2 Supply management

The main measure to be considered for energy supply management is the use of renewable energy, both for production of thermal energy (solar water heating) and for generation of electrical energy (through the use of photovoltaic energy, wind energy, biomass etc.).

Thermal energy generation: solar water heating.

In order to choose the appropriate solar water heating system for a social housing unit, it is necessary to verify what are the market-available options, the cost and expected performance of each alternative, consumption profiles, local climate, and technical characteristics of the installation (SOUZA; ABREU, 2009). It is also important to check the level of maintenance required by the system, the involvement of the users in its operation and the awareness of consumption of both water and energy.

More specifically, it is important to pay attention to the following performance requirements:

- Adequate levels of sunlight: The hours of sunshine should be checked at the location where the system is to be installed to ensure they are adequate. In general, the state of São Paulo has acceptable average daily sunlight periods, that vary between 6 and 8 hours. The global average radiation in the southeast is of 5,6 kWh/m^2 and the mean on an inclined plane is 5,7 kWh/m^2. Daily sunshine values can be found in the Brazilian Atlas of Solar Energy (PEREIRA et al, 2006).

- Viability of the positioning of the panels: It is also important to consider the viability of positioning the collector panels to obtain their maximum efficiency. The panels should be orientated towards true North, having up to a deviation of around 30° towards the east or west. In the same way, they should be positioned at an inclination angle depending on the latitude, giving preference to inclination of the latitude increased of 10° to increase the efficiency of the system in the wintertime.

- Solar fraction attained: The Technical Quality Regulation for Energy Efficiency Levels of Residential Buildings /RTQ-R[2] (MME, 2010) establishes the levels of efficiency depending on the solar fraction obtained. A fraction between 60% and 69% corresponds to level B and 70% or more corresponds to level A. The Casa Azul label, developed by Caixa (JOHN et al, 2010) already encourages installations with an attained solar fraction of 60% to 80%. Finally, Law n° 14.459, that makes the installation of solar water heating systems compulsory for half of the use of energy in new buildings in São Paulo, encourages buildings that reach 40% or more of solar fraction.

- Maintenance: It is very important to think about the ease of maintenance as a criterion in the choice of the system. When the solar system used in multi-family buildings provides energy to individual systems (individual heaters), the responsibilities for operation and maintenance of the systems should be clarified.

- Individual metering: The adopted solutions should enable individual metering, even in multi-family housing.

- Guaranteeing high performance of the system: Antifreeze substances are mandatory and should be provided by the supplying company upon installation of the system, in locations where this is necessary, due to the occurrence of freezing phenomenons in some of the cities in the State of São Paulo.

- Establishing plans for Measurement and Verification (M&V): The system should be monitored as often as possible.

- Supply point: The hot water should primarily be used to supply the shower.

- Efficiency of the system's components:

  - Collectors: These should provide high energy conversion efficiency and, preferably, be labelled level A or B by the Brazilian Labelling Program (PBE) INMETRO. The total area of the collectors should be related to the required storage volume.

  - Storage tank: The storage tank should be sized to meet the demand for hot water by users according to standards and can be integrated with or separated from the collector. Storage tanks should preferably have the PROCEL label and should have adequate thermal insulation and the minimum storage capacity compatible with the proposed sizing. Attention should be paid to the distances between the storage tank and the collector and between the storage tank and the point of use.

  - Backup supply: This backup is required in case of supply discontinuity. It can be a gas or electric system. It should be easy to turn off (for the user) or (preferably) automatic.

- Qualified installation: Preference should be given to companies and installers that have been certified by QUALISOL (Qualification Program for the Suppliers of Solar Water Heating Systems) and QUALINSTAL.

- Performance requirements of the relevant standards:

  - NBR 15569 – Standard for solar water heating
  - NBR 5626 – Standard for cold water installations
  - NBR 7198 – Standard for hot water installations
  - NBR 5410 – Standard for backup electric heating
  - NBR 13013 – Standard for backup natural gas heating
  - Other standards or municipal legistation (laws)

2 Regulation that is currently in development and will be available for download from March 2011. It will be available at: http://www.labeee.ufsc.br/.

Generation of electric energy

The use of non-polluting, renewable sources of energy for the generation of electrical energy is not yet widespread in the country, especially in social housing, prinicipally due to the high cost of implemenation. Renewable energy can be obtained using photovoltaic panels, wind turbines, or biomass among others. Important requirements to ensure performance include:

- Demonstration of efficiency by the manufacturer;
- Assessment of the estimated percentage of energy that will supplied;
- Evaluation of the alternative by studying costs and benefits, considering the availability of the inputs on the site and suitable dimensions for incorporation of the system;
- Maintenance;
- Durability.

Wind energy can be incorporated to buildings, but it is a technology suited to locations with high speed and constant wind. Biomass can be considered for the generation of electrical energy and/or biogas for supply to the kitchens.

Photovoltaic energy

One of the alternative sources for the production of electrical energy that will be increasingly incorporated in residential buildings in the future, according to current trends, is photovoltaic energy. For single-family dwellings, it can be predicted that: installed photovoltaic energy systems will supply enough electricity to satisfy the unit's needs; the systems will allow to limit the consumption of energy from the grid (leaving the families in the consumption range that allows for reduced rates); and finally more powerful systems will allow to "export" energy to the grid and generate profits.

In multi-family buildings, the positive outcome would be to supply all the energy required for operation of the building through photovoltaic energy. However, multi-family buildings present challenges considering that a smaller area is available for installation of the system and that the demand is more important. In urban areas, and if the infrastructure is available, it would be more suited to integrate photovoltaic systems that are connected to the grid, leaving isolated systems for areas that do not have grid connections. The final selection will depend on the financial viability of the system.

More specifically, the performance requirements for an integrated photovoltaic system depend on some variables:

- Site: the system can be implemented as a protection element (on walls, as part of the roof). At São Paulo's latitude, the incident radiation on vertical elements, such as walls, is usually signicantly inferior (around 40 to 50% less) when compared to radiation on low inclinations areas such as roofs. For this reason, it is advisable to integrate the systems into roofs or protective elements that have a lower inclination.
- Radiation level (in $Wh/m^2/day$) reaching the plane where the system will be placed: The radiation incidence on the proposed plane should be checked considering the monthly daily average radiation. The incident radiation is determined by the latitude, longitude and altitude of the site and the values are measured in solar radiation measurement stations in the country. The position of the solar modules relative to North (azimuth) and the angle of inclination of these will also have an influence. In general, photovoltaic modules oriented towards true North with an inclination angle depending on the local latitude present the highest levels of radiation, while horizontal panels do not present very big losses compared with the ideal.
- Installed nominal capacity (in kWp): The capacity installed should match the percentage of the electrical energy use that one aims to supply with the photovoltaic system. The final installed capacity should be distributed in an equal way in each of the phases that comprises the building electric system (which can be triphasic or monophasic).
- Efficiency of the photovoltaic modules (in %): The efficiency of the photovoltaic panels is determined by the adopted technology. The most common technologies are crystalline and amorphous silicon. Amorphous silicon is used in rigid modules (which can be opaque or semitransparent) and flexible modules (opaque). Flexible modules can easily be adapted for roofing, and be curved if necessary. Amorphous silicon provides the lowest percentage of efficiency, around 6%, but also the lowest cost. Crystalline silicon modules provide higher efficiencies on average, with those made of polycrystalline silicon at around 12% and up to 19% for some monocrystalline models. Thus, it is essential to determine the required efficiency of the system, which will be linked to the cost and the available area.

- Choice of inverters: The choice of inverters depends on the properties of the photovoltaic module being used and the nominal power being installed, so that the characteristics of the inverter support the operating condition of the chosen photovoltaic arrangement in relation to the maximum input power (Wp), operating voltage (V), open cicuit voltage (V), operating current (A) and closed-circuit current (A). Care should be taken in the selection of inverters because they cannot be underutilized; the maximum input power of them should be very close to the nominal power of the installed system. Space for the inverters should also be provided for in the design.
- Area required for the system: The available area should allow to incorporate all the required photovoltaic panels to achieve the target nominal capacity. The required area will be determined by the installed power and by the performance of the photovoltaic modules.
- Shading: It is important to check the shading patterns at the site because those can have a detrimental effect on the performance of the system by reducing the incident radiation on the installed photovoltaic modules. Therefore, for places in shade throughout the year or those in shade at some times of the day the precentage shading should be checked to validate the implementation of the system and arrange series and parallel connections of the modules so that the shadow do not affect the whole system, but only a part of it.
- Energy generated by the system (in kWh/day, kWh/month or kWh/year): It should be verified whether the system is covering 100% of the energy use, less than 100%, or more than 100%. If additional energy is produced, arrangements should be made to export it to the local utility network, so that it can generate profit for the users. Relevant public policies are currently being reviewed.

Besides the requirements listed above, installing a photovoltaic system also requires to plan for electric wiring ducts for cables, supports or fixation products for the photovoltaic modules, planning enough space for the other components of the system (keys, inverters, energy meter etc.) as well as electric ducts for the grid connection.

2.1.2.3 Quality in the installation, maintenance and operation of building systems

Care in the design and installation of components is of extreme importance for the expected performance of the systems. This is the reason why preference should be given to installation by companies and professionals with proven experience in the sector.

Regarding durability and ease of maintenance of the building systems, the NBR 15575 (ABNT, 2005) presents parameters for façades (part 4) and roofs (part 5), as well as general requirements for buildings (part 1). According to this standard, the unit's elements, components and installations submitted to periodic maintenance and looked after according to the supplier's specific instructions should maintain their functional capacity throughout the useful life predicted in the design.

Therefore, periodic maintenance is very important for the correct and continuous operation of the systems. The user should be educated; this can be done by manuals or workshops at handover, explaining concepts of thermal comfort and energy efficiency, making the link with the equipment and maitenance requirements. It is also important, when thinking in terms of multi-family buildings, that the management of the condominum is done by companies or individuals that understand maintenance of building systems. It should also be highlighted that replacement of parts or elements will be needed to maintain the same level of efficiency as provided by original elements proposed in the design.

2.2 Hydraulic building systems and water use and demand management.

A water use analysis must focus on the different dimensions of the importance of water; therefore we will consider aspects of environmental, social, economical and cultural sustainability.

From a social point of view, the appropriate use of water, in other words the availability of water of good quality and the appropriate collection, treatment and disposal of waste water, directly influences the quality of life of building occupants. The water quality and treatment has an impact on the direct building environment and the broader urban or rural environment. Adequate water and sanitary infrastructure results in better health and hygiene conditions, directly improving life quality.

Water has an economic value, not only through direct use (personal hygiene, drinking water, washing purposes) but also through its indirect use in production processes.

The environmental impacts of water use are linked to its social and economic value. To minimize the impact of water use on the environment, we must consider sustainability as encompassing the entire life cycle of the resource: sustainable water use includes water supply management, quality of infrastructure, distribution networks, and basic sanitation, as well as rational water consumption by the final user. Water quality and sound management can be achieved through consideration of the risk criteria and verification of use and quality.

Sustainability in water use in buildings relates mainly to managing the supply and demand of water for the users, protecting the health of consumers and the quality of productive processes. Addressing water use in buildings has the objective to reduce consumption and avoid losses, guarantee quality, and avoid negative impacts on the environment and the society caused by inappropriate disposal of used water.

The performance of hydraulic building systems is essential to achieve this objective. Buildings' evaluation frameworks often include water quality and rational water use as key aspects to ensure sustainability.

According to Kalbusch (2007), evaluation of hydraulic building systems and building water use is conducted by evaluating the performance of buildings against several requirements:

- Reliability, quality and ease of maintenance of hydraulic and sanitary building systems;
- Water health and quality;
- Water demand management;
- Water supply management (rainwater harvesting, water recycling and reuse);
- Pressure on local infrastructure (rainwater drainage and wastewater treatment);
- Buildings' interference on underground water (aquifers); and
- Quality of materials and hydraulic components applied.

On the following pages, a more detailed description of these requirements is provided.

2.2.1 Hydraulic and sanitary building systems

The Brazilian standard NBR 14037 (ABNT, 1998) and the performance standard for residential buildings up to 5 floors (ABNT, 2004a) have expressed the need for a user manual that provides information on the routine maintenance of hydraulic building systems, both for potable as non-potable water. This manual should include information on the conservation of water, precautions to maintain the water quality and a technical explanation of the functioning of the hydraulic systems in order to guarantee a longer use life.

Another potential barrier to quality is the lack of evaluation of constructed buildings. Over the life cycle of the building, the lack of information can hamper the possibility to renovate or maintain systems appropriately.

Users' capacity

Building the capacity of users to conserve water and maintain hydraulic systems is crucial. Information is usually provided through manuals or information guides in the case of new buildings, but these do not necessarily get delivered to the final user. Construction managers and local utility companies have to inform users of the benefits of water conservation and of appropriate maintenance of the building systems.

In existing buildings, building managers and utility companies can organize awareness campaigns to guarantee constant improvement in water management and reduction of water consumption, highlighting the benefits for society but also the importance to preserve health, safety and quality.

Reliability

It is necessary to clearly identify the different water systems in the building, to differentiate potable and non-potable water systems. Potential risks and failures of the hydraulic system during design, construction and operation can result in higher maintenance and operation costs and can have serious repercussions on the systems and the end user. The standard NBR 13969 (ABNT, 1997) recommends adequate identification of recycled water tanks and distribution systems, for instance through a different color for water pipes. International standards, such as the Guidelines for water reuse (EPA, 2004) recommend colouring the non-potable water.

Maintenance

The norm NBR 5626 (ABNT, 1998) demands that the project provides easy maintenance solutions to avoid difficulties in operation and future maintenance costs.

Hydraulic systems with fewer connections, often accessible or built in easy accessible hydraulic walls, facilitate the maintenance. The maintenance of the system is a continuous action, which is preferably scheduled and executed by trained professionals. It is important that all the information related to the hydraulic building systems is available to the building manager and inhabitants

Quality

Another important aspect is temperature control of buildings' hot water systems. It is important to guarantee the health, security and comfort of the residents. Water quality should be controlled, and prevention measures should be established to avoid proliferation of harmful biological agents. For instance, contamination by Legionella pneumophila bacteria may occur in cases of water temperature use between 25°C to 50°C, stagnant water, long periods of non-use, and sedimentation leading to formation of biofilm.

It is crucial to consider, in the design phase, solutions to avoid health risks, for instance by limiting the maximum water temperature through the heating system. According to the local context, the design should also consider potential water supply risks (peak periods, maintenance capacity, distribution losses or disruption of supply).

2.2.2 Health and water quality

Ensuring delivery of safe and healthy water is the key purpose of hydraulic building systems. Therefore, it is important to preserve the drinking quality of water and avoid contamination, from the water storage through the distribution pipes, up to the moment of consumption. The quality of materials used and the appropriate use of the different materials and components are important to preserve the users' health.

2.2.3 Water demand management

Water conservation has a positive environmental, social and economic impact. From an ecological standpoint, the implementation of water conservation measures results in the preservation of water resources, contributing to sustainable development. From a social standpoint, it allows a better distribution of water resources, since surpluses are generated. From an economical standpoint, it reduces the costs related to water inputs, and allows lower maintenance and operation costs for water systems.

Thus, water management in buildings is related to two essential components:

- Technical: this component encompasses the actions of evaluation, measurement, technology implementation and water use procedures; and
- Human: this dimension relates to the users' behaviour and perception regarding water use, as well as measures established to influence consumption activities (including commercial use).

Any technical measure should be integrated to a human approach for successful implementation of water conservation programs, in new and in existing buildings. In the case of a new building, the building systems design should consider the optimization of water consumption. The design can consider, for instance, the use of alternative water sources for non-potable use (through separate water transportation systems), solutions to optimize the water delivery systems, implementation of accessible hydraulic systems, or intregration of consumption management tools. The integration of a water management approach in a new building has the advantage of not requiring review of existing systems and behavior, but does require a thorough preliminary feasibility study before implementation.

In the case of existing buildings, the implementation of water conservation programs requires first of all an assessment of the current available information regarding the building system, the different uses of water and the users' interaction with the system.

For water management demand, all information regarding water use in the building should be available in order to have full knowledge of the operation requirements. The identification of different water uses in the building should be done through an analysis of the hydraulic system, the users and processes responsible for water consumption, as well as the historical data on consumption.

The assessment of the different processes responsible for water use allows evaluating the actual water consumption and the necessary interventions to reduce consumption and consequently reduce waste water. The evaluation should include water consumption, leakages, hydraulic equipments and pressure of the hydraulic system.

Identifying consumption sources

Reducing losses due to leakages is a key component of a water management plan. The evaluation should consider materials and components that should be included or substituted (for existing buildings) and provide an analysis of potential water consumption reduction and related costs. Invisible water leakages should also be identified through appropriate tests.

In order to establish consumption indicators, it is important to understand the processes and users responsible for water consumption. This will allow to install individual water meters, for each user to evaluate and control water consumption. In the case of vertical buildings, individual metering also allows to identify leakages and influence habits towards water consumption reduction.

Therefore, in order to stimulate rational water use, it is often necessary to establish specific procedures and routines for each water-consuming activity, addressing water quantity and quality. These procedures should be easily applicable and understood by the users. Often rational water use is less related to the use of appropriate technology than to the behavior of the user.

Appliances and equipment

Hydraulic equipments should be adjusted to the expected use: requirements should be established based on the required pressure, temperature, and final use. The system can then deliver maximum comfort to the user while allowing reduction in consumption. The Brazilian Programme for Housing Quality and Productivity (PBQP-H) provides standards for hydraulic components, guaranteeing the materials quality.

The pressure in the hydraulic systems should be appropriate to the required uses and functioning of hydraulic equipment. Pressure control can deliver significant results in control of water consumption. Figure 5 summarizes the actions to undertake for water demand

2.2.4 Water supply management.

Buildings are supplied in water through the public network, managed by the local utility company, providing water and basic sanitation services, or through the following sources:

- Direct collection from springs;
- Groundwater;
- Harvested rainwater;
- Greywater reuse.

The selection of one of these options for water supply should be done considering not only the direct acquisition costs, but also the potential costs related to supply failures, maintenance and operation costs, as well as the guarantee of water quality that would allow to safeguard the health of users both inside and around the building.

Negligent use of alternative sources or lack of management of these sources can create risks for the consumer and have a negative impact on activities requiring water use. The potential use of alternative water sources should be evaluated by an expert, and a Water Management System should be established for continuous monitoring.

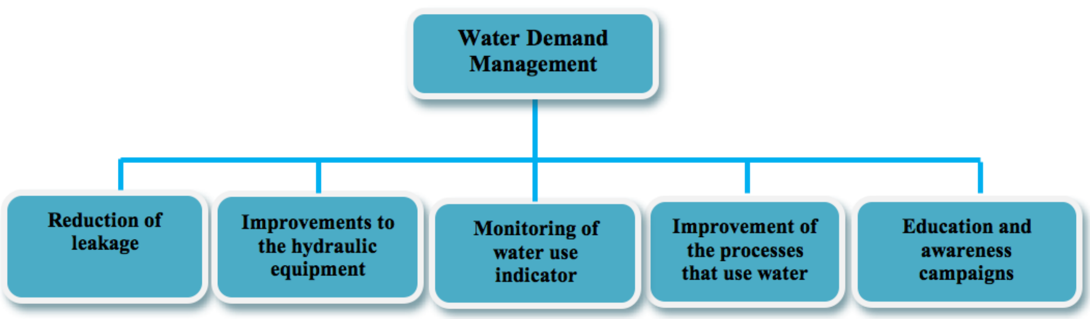
Local public network

To evaluate the water supply provided by the utility company, the first step is to verify the availability of the public supply. The price may vary according to the type of building. Some utility companies also supply reused water for non-potable uses.

Springwater

To collect springwater, it is important to follow legislation and consult with relevant governmental environmental organizations to identify if the water is suitable for extraction and if the watershed provides safe water. The local inspection body can then issue a permit for water collection.

Figure 5 – Action scheme for water demand management.



Groundwater

The use of groundwater is regulated through specific legislation. A license from the department of water and sanitation (DAEE), as well as a specific authorization from a geologist appointed by the relevant Regional Council of Engineering, Architecture and Agronomy (CREA), are required to drill a well. The user becomes then responsible for realizing the extraction in an appropriate manner, including avoiding pollution of the subsoil.

Rainwater

To assess the possibility of rainwater harvesting, a simulation of the viability of harvesting and storage of water should be executed, based on historical pluviometry data (monthly measurements) provided by local meteorological institutions. The potential demand should be estimated, to calculate the required collection area and watertank volume. An important advantage of rainwater storage and use, besides reduction of potable water consumption, is the contribution to preventing potential floods.

Greywater

For reuse of greywater (treated wastewater), the feasibility study should include a quantitative and qualitative assessment of the effluent, to identify the type of processing required. Greywater may not require treatment, depending on the intended use. Quality requirements for each intended use should be verified before defining the necessary processing technologies.

The use of alternative water sources for non-potable use is important for resource conservation, although it should be highlighted that there are also some risks associated with their applications.

According the Water Thematic Committee of the Brazilian Council for Sustainable Construction (CBCS), the following important precautions have to be considered while using alternative water sources:

- Risk points that may lead to contamination of potable water;
- Water quality parameters for non-potable water uses, including specific legislation and related standards;
- Specific precautions required by cross-connections (potable water systems and non-potable water systems), as well as requirements for design, execution and operation of systems;
- Need for a water tank for storage;
- Requirements for materials to beused in pipes,valves and connections;
- Training of the end user to minimise risks; and
- Project visibility to raise user awareness.

Figure 3 summarizes potential actions for water supply and demand management.

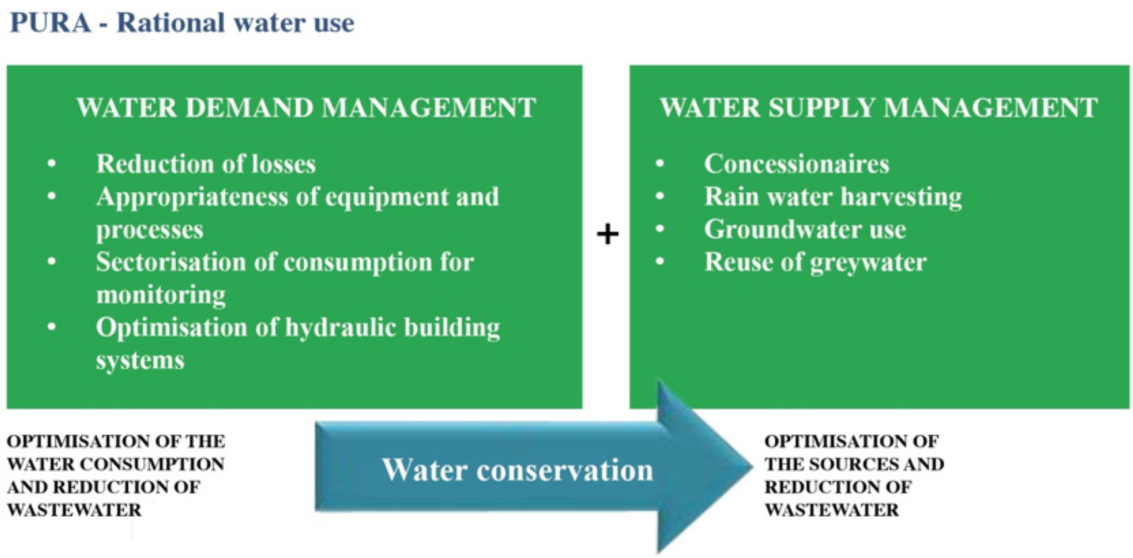


Figure 6 – PURA (Programme for Rational Water Use): Actions for water supply and demand management.

We can therefore identify core measures for water conservation:

- Choosing appropriate water fixtures (water efficient toilets, taps, and showers);
- Avoiding leakage;
- Identifying and classifying water use and responsible users;
- Adapting processes and consumption patterns;
- Recycling water;
- Reusing water;
- Use of groundwater; and
- Rainwater harvesting.

Again, the selection of alternative water sources for non-potable uses implies specific demand and supply management actions to ensure water quality and safety for the user.

2.2.5 Load on local infrastructure (the interference on aquifers, rainwater drainage and sewage)

The impact of the building on the aquifers

Site selection and building positioning on the land should be carefully done. Minimum distances from natural resources need to be respected, as well as precautions related to the use of groundwater. It is crucial to be informed of and respect local legislation and requirements of local utility companies.

Rainwater harvesting

In the area of water management, rainwater harvesting offers positive environmental, economic and social benefits, especially during seasons with high rainfall. When water storage systems are included in a building design and construction, the manager should try to assess the possible use of water for non-potable uses, therefore making use of the initial investment.

In some cities in Brazil, including São Paulo, construction of small rainwater tanks is compulsory. These tanks allow to control the flow of water into the sewage system, therefore reducing the risk of urban floods. However, according to Gonçalves (2004), the stored water could potentially be used for landscape irrigation, washing and other non-potable uses.

A greater effort should also be made to improve rainwater infiltration in local soil. This can be achieved through permeable pavement and/or other drainage systems that store water in the ground until infiltration is realized.

Besides permeable pavement, the main measures for infiltration of rainwater in the soil identified by Kalbusch (2004) include infiltration trenches, swales and wells.

Sewage treatment

It is necessary to properly collect waste water generated by buildings to ensure its appropriate treatment and disposal. Wastewater collected through the public network has to respond to local legislation and established quality standards. In the absence of a public sewage system, an in-situ treatment system should be planned for, also according to local legislation.

Resolution n°357 of the National Environment Council (CONAMA) highlights that effluents from any polluting source can only be disposed of, directly or indirectly, in water bodies if they meet specific standards of pH, temperature, flow and proportion of sedimentary materials, oil and greases (BRASIL, 2005). This resolution also sets standards for sewage discharge that limit the maximum amount of organic and inorganic substances per litre of wastewater.

2.2.6 Quality of materials and hydraulic components.

Sustainable hydraulic systems depend highly on the choice of materials. The Brazilian Programme for Housing Quality and Productivity aims at establishing and enforcing quality standards for materials and components in civil construction. Some construction materials are concerned by related Sector Quality Programmes, which allow to address the performance of materials in a specific sector while avoiding unfair competition.

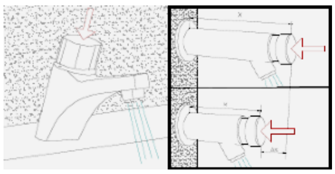
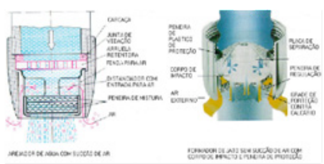
The use of materials and components that do not comply with requirements leads to low-quality buildings and civil infrastructure. This harms the end user, but also the companies and the urban environment as a whole. Waste, low performance, urban pollution and housing deficit are issues linked to non-compliant materials.

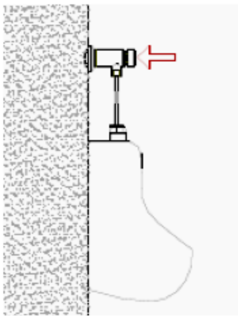
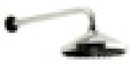
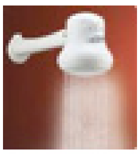
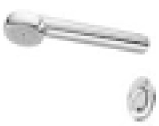
A specific website (found at http://www4.cidades.gov.br/pbqp-h/projetos_simac_psqs.php) allows to track and be informed of the quality evolution of different materials.

Besides construction materials, finishing materials also have an impact on durability, and can contribute to sustainable resource use. According to Schmidt (2004), one of factors that influence the level of water consumption of a building is the requirements for china and sanitary metals.

Water saving fixtures have specific installation, operation and maintenance requirements. Each piece has an appropriate use, and should be operated and maintained by the relevant user. Producers should provide information for appropriate installation and operation, so that users can use the features correctly and increase the product's durability. Relevant maintenance actions should be planned in advance to prevent and repair defects.

Table 3 presents the main characteristics of water saving devices and appliances that are currently available on the Brazilian market.

Water Fixture	Type	Main Characteristics
FAUCETS	Conventional faucet 	Device to control the water flow. When actioned, it releases a water flow, which can be controlled according to the needs of the user.
	Hydro mechanical faucet 	Control of the water flow is obtained by the incorporation of a flow reducer in the faucet. Users cannot control the flow. The timing of the water flow also determines the rational use of this device. The period should not be too short, to avoid having to push several times during one operation, which causes discomfort. This device can be installed in public bathrooms and dressing rooms of schools, offices, soccer stadiums and hospitals.
FAUCET AEREATORS	Aerators 	An aerator is a component installed at the end of the spout of the faucet in order to reduce the section where the water passes. The aerator uses a perforated head or fine fabrics and has holes in the side surface to allow an air intake during the water flow. In general, they can be divided in devices that have air intake or do not. The use of an aerator has two purposes: to control the diffusion of the water flow and to reduce the water flow of the faucet, and thus the water consumption. Aerators are recommended for all faucets except the ones used for cleaning and water collection, where the user prefers a higher flow to reduce waiting time. In kitchens, it is recommended to install the aerator as a shower head, in order to facilitate certain activities. There are some devices which have both functions: aerator and shower head. In general, the modification of the function is done by a switch button, which allows the user to use a concentric or diffused water flow.

Water Fixture	Type	Main Characteristics
URINALS	Individual (conventional) 	Individual urinals are industrial mass products, mainly in ceramics. The majority of the urinals in Brazil are of this type.
DISCHARGE DEVICES FOR CONVENTIONAL URINALS	Hydro mechanical flush 	This device is inserted in a metallic body, through which the water passes before reaching the urinal. In order to flush after the use of the urinal, the user has to push the button, which releases a water flow into the urinal. Immediately after the release of the button by the user, the water and the spring push the piston back in his place. This type of equipment can be used for instance in company toilets, schools, shopping malls, hospitals, clubs, offices, stadiums and airport terminals.
SHOWER HEADS	Shower head for mixed water (hot and cold) 	There is a big variety of types and models of shower heads on the market, with different water flows. A passive intervention in public and private showers is the introduction of a flow restrictor device. One of the advantages of the use of a flow restrictor is that the pressure remains constant. There are flow restrictors with different pressure ranges but all follow a minimum recommended water pressure.
	Electric shower head 	It is not recommended to use flow restrictor devices in combination with electric showers, since they may interfere with the operation.
	Timer devices to control the flow release 	Another way of reducing water consumption in showers is the use of timer devices to control the flow release. The most common device is the push button. The disadvantage of this system is that the regulator can be inappropriately locked, resulting in water leaks or even in non-functioning of the device. The timer devices work with hydro mechanic forces and close automatically after a predetermined period.

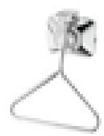
Water Fixture	Type	Main Characteristics
SANITARY BASINS	Without water tank 	Currently, this type of sanitary basins is provided in the market with an approximately 6 liters per flush ratio, needed to discharge properly.
	With water tank 	A variant exists on the market, and is called the “dual-flush” device. It has two types of discharges, both handled by a different button: one uses six liters of water and is used for flushing waste water containing solid components, the other one consumes three liters and is used if there is only urine in the basin.
DEVICES TO INITIATE THE DISCHARGE IN SANITARY BASINS	Integrated flushes 	These devices allow to control the water flow. Most models have a fixed six-liters-discharge. When the user initiates the flush, he releases a fixed flow of a predetermined volume, unrelated to the time the button is pressed. In order to release a new flow, the button needs to be initiated again. Another type of device is a flush integrated in the wall and initiated by a motion sensor. The user needs to stay for a certain amount of time in front of the sensor, often 5 seconds, in order to automatically initiate the flush when he leaves the sight of the sensor. The volume for each flush can be set on six liters per flush.
	Apparent flush valves 	The flush action is done by a handle on the valve body. As long as the user holds the handle, the predefined flow is being discharged. In order to discharge a new volume of water, the handle needs to be pulled again. This system is mainly used in locations with a tendency of vandalism. Since the revealed parts are in resistant metal, it is nearly impossible to damage them without tools. The system is resistant to heavy impacts.
	Embedded water flush tanks 	One option for the discharge of 6 liters per flush is the use of the embedded water tanks. These tanks can be built in a masonry wall, but they are most often built in a dry-wall. Before the installation of this type of device, the dimensions of the wall should be measured, to see if the wall is thick enough to hide the tank.
FLOW REDUCTION DEVICES	Flow reduction devices 	There is a linear relationship between the flow and water pressure. The reduction of the first results in a reduction of the second. Therefore the reduction of pressure results in a loss of water release in the system, which results in a reduction of water flow. This system can be installed in the water pipes at the entrance of specific places in the building, where the water pressure is higher, in order to regulate the water pressure. This device keeps the flow constant within a certain pressure range.

Table 3 – Main characteristics of hydraulic equiments (adapted from SAUTCHUK, 2004)

Table 4 compares the water consumption of a conventional device to the consumption of a water-efficient device. Water savings are expressed in percentage.

DEVICE	WATER CONSUMPTION/ CONVENTIONAL DEVICE	WATER EFFICIENT DEVICE	WATER CONSUMPTION WATER EFFICIENT DEVICE	SAVINGS IN %
Basin with integrated tank		Reduced water use basin (VDR)	6 litres/flush	
Basin with well regulated valve		Reduced water use basin (VDR)	6 litres/flush	
Basin with integrated water tank and double valve.	6 litres/flush	Dual flush	6 and 3 litres/flush	18
Low pressure shower (hot and cold) (6mwc)	0,19 litres/second	Flow restrictor 8 l/min	0,16 litres/Second	16
High pressure shower (hot and cold) (15- 20mwc)	0,34 litres/second	Flow restrictor 8 l/min	0,13 litres/Second	62
Low pressure sink faucet (6mwc)	0,23 litres/second	Water aerator 6 l/s	0,10 litres/Second	56
High pressure sink faucet (15-20mwc)	0,42 litres/second	Water aerator 6 l/s	0,10 litres/Second	76
Low pressure general purpose faucet (6 mwc)	0,26 litres/second	Flow control	0,13 litres/Second	50
High pressure general purpose faucet (15-20mwc)	0,42 litres/second	Flow control	0,21 litres/Second	50

Table 4 – Relation between conventional equipment and water efficient equipment
(source: MENDES, 2006)

Table 5 summarizes performance requirements for hydraulic building systems, to help the user in practical operation. This table is based on the ABNT standard for buildings up to five floors.

Item	Requirement	Criterion	Details
STRUCTURAL SAFETY	Mechanical resistance	Appropriate fixation	
	Resistance to dynamic forces	The components should not cause impacts and vibrations which put the structural stability at risk.	The discharge valves, fast closing metals and switches cannot cause an extra pressure on the joints of more than 0, 2 Mpa.
FIRE SAFETY	Fire fighting with water	Water storage for fire fighting	The volume of the water reserved for fire fighting has to be calculated according to the local state decree or by the technical instruction of the local firemen unit, or, if not available, according to the NBR 13714 standard.
	Fire fighting with a fire extinguisher	Types and positioning of fire extinguishers	The fire extinguishers must be correctly classified and positioned according to the standard NBR12693/93. They must carry the INMETRO label, guaranteeing compliance.
SAFETY IN USE AND OPERATION	Risks of electric shocks and burns	Groundwiring of appliances	All the pipelines, equipment and metallic components of the hydro sanitary system must be directly or indirectly groundwired
		Groundwiring of heating devices	The electric devices related to water heating must be properly groundwired by a protection conductor conforming to standard NBR 5410.
		Leakage current in heating devices	The electrical devices related to water heating must be properly groundwired ground by a protection conductor conforming to standard NBR 5410.
		Maximum temperature of heated water	Showers up to 7, 8 Kw: temperature variation without thermal protector = 50°C, with protector = 55°C.
			Faucets up to 9 Kw temperature variation without thermal protector = 50°C, with protector =55°C.
			Heating systems up to 5, 5 Kw: temperature variation without thermal protector = 55°C, with protector = 55°C.
			Heating systems from 5, 5 Kw up to 9Kw: temperature variation without thermal protector = 75°C, with protector = 75°C.
		Security devices in electric accumulation heaters	Electric storage heaters, used for the heating of water, must be equipped with a relief device in case of over-pressure. They must also carry a safety function which disconnects power in case of overheating.

Item	Requirement	Criterion	Details
SAFETY IN USE AND OPERATION	Risks of explosion or intoxication by gas	Security devices in gas accumulation heaters	Gas storage heaters used for the heating of water must be equipped with a relief device functioning in case of overpressure. It must also carry a safety function which disconnects the gas in case of overheating. The installation must be done in such a way that it protects the nearby equipment against potential damage caused by pressure.
		Installation of gas equipment	The installation of the equipment that uses gas fuel in residential areas must be done correctly.
	Security during use of components and	Prevention of injuries	All components manipulated by users should not contain sharp corners or rough surfaces.
		Maximum surface heat of devices	The surface temperature of components that contain warm water must be maximum 55°C for metallic surfaces and maximum 65°C for non metallic surfaces.
WATER TIGHTNESS	Water tightness in infrastructure	Water tightness in water systems	The pipelines of the building system should not reveal leaks when subjected to a hydrostatic pressure of minimum 1.5 times the predicted pressure in this section, in static conditions, and in no case with pressure below 100 kPa.
		Water tightness in equipment	Parts and home water tanks can not reveal any leaks when subjected to a normal hydrostatic pressure during use.
		Water tightness in the sewerage and drain infrastructure	The pipelines of the building's sewage and drain systems can not reveal any leaks when subjected to a static pressure of 60kPa for duration of 15 minutes, if the test is done with water. If the test is done with air pressure, the static pressure is 35 kPa, also for duration of 15 minutes.
		Disconnectors of the building and sewerage system	Disconnectors used in the building sewage system must present water-closing systems with an minimum height of 0,05 m.
		Water tightness in the drain installation	The joints in the rainwater gutters must be watertight.
THERMAL PERFORMANCE	Water temperature in use	Need of heating system	In the regions with an absolute minimum indoor temperature of less than 8°C, warm water must be provided for at least the shower.
ACOUSTIC PERFORMANCE	Noise reduction	Speed of the water outflow	The speed of the water runoff in the pipelines of the buildings cannot be higher than the value specified by the standard NBR 5626.
		Noise generated by vibration	The pipelines, equipment and other components that are subject to dynamic forces should be properly isolated to not cause vibrations in the supporting structure.

item	Requirement	Criterion	Details
HEALTH AND HYGIENE	Water contamination due to Infrastructure components	Independance of the water system	The hydro sanitary system must be physically separated from any other water transportation installations that carry non potable water or fluids with a low, unknown or questionable quality.
		Selection of sealants	The joints of the water pipelines cannot contain zircon, lead or other sealing materials that can contaminate water.
		Limitation of heavy metals in the PVC water pipelines	The PVC coldwater pipelines used in buildings need to obey standard 5648, related to water contamination by heavy metals.
	Biological water contamination	Risk of biological water contamination in the pipelines	All the apparent installation components must be made in washable and waterproof materials to avoid impregnation of filth and the development of bacteria or biological activities.
		Risk of water stagnation	All the components of the hydraulic system must avoid water stagnation, which can lead to the development of biological activity.
		Underground potable water pipelines	The underground water pipelines must remain at a horizontal distance of minimum 3,0 m from every potentially polluting source, as e.g. sewage, septic tanks, sinks, infiltration trenches, etc. If the crossing of the sewerage and the underground water pipelines is unavoidable, the bottom of the water pipeline must remain at least 0.30 m above the upper generating line of the sewage pipeline.
FUNCTIONALITY AND ACCESSIBILITY	Operation of the water system	Dimension of the water system	The dimensions of the pipelines of the hydraulic building system need to be in accordance with the NBR5626 standard, with as a base the flows indicated for the project and respecting the fixed minimum pressures for the several use points.
		Operation of the discharge devices	The toilet tanks and flush valve need to obey the requirements described in the standard NBR11852 and NBR12904 related to the flow and volume of water use.
	Avoiding spatters	Limitation to the faucets' water dispersion	During maximum flow, with a 100 kPa pressure, the faucet should respect the requirements defined in standard NBR 10281.
	Continuity of water provision	Dimensions of the water tank	The gutters and drain pipelines' dimensions need to be in accordance with standard NBR10844.
	Operation of the rainwater systems	Dimensions of the gutters and drain pipelines	The components that are used, including manipulation records, need to have wheels with formats and dimensions adapted to their specific use.

item	Requirement	Criterion	Details
TACTILE COMFORT AND ERGONOMICS	Ergonomy in the use of building facilities	Ergonomic adaptation of equipment	The components that are used, including manipulation records, need to have wheels with formats and dimensions adapted to their specific use.
DURABILITY AND MAINTENANCE	Lifetime of hydro sanitary facilities	Planning and installation of the hydro sanitary facilities	The quality of the design and installation of hydro sanitary systems must guarantee their durability in terms of maintenance of their essential functions, during the lifetime of the product, under normal circumstances, use and operation. The design and installation of the hydro sanitary systems need to respect the prescriptions of the following standards: NBR5626, NBR8160, NB7198 and NBR10844.
		Durability of materials, equipment and parts.	The components of the hydro sanitary systems (pipelines, connections, sanitary metals, sanitary components etc.) must have an expected lifetime compatible with the lifetime of the project. The specific periods are defined in table 7 of the document "Desempenho de edifícios Habitacionais de até cinco pavimentos- parte1: Requisitos Gerais" (Performance of residential buildings of up to five floors - part1: General requirements).
	Maintenance	Inspection of apparent sewage or drain pipelines	The visible sewage and rainwater pipelines must be accessible for inspection so that every area of the pipeline can be reached with a flexible rod, according to standard NBR 8160.
		Inspection of underground sewage or drain pipelines	In all the underground sewage or drain pipelines, manholes must be integrated, in such a way that the distance between two consecutives manholes does not exceed maximum distance as defined by standard NBR8160, so that every spot of the pipeline can be reached with a flexible rod.
ENVIRONMENTAL ASPECTS	Rational water use	Water consumption in sanitary basins	Sanitary basins used must have a reduced discharge volume, defined by specification in the NBR6452 standard.
		Water flow of faucets	The faucets of the lavatory and the washbasins need to be equipped with aerators.
		Water flow of showers	The flow of the showers for residential use can be maximum 9 litres per minute.
	Soiland groundwater contamination	Treatment and discharge of waste water	The building sewage system must be connected to the public utilities' system or to a water treatment and disposal system.

3 Technical evaluation of alternative solutions

Table 6 presents a summary of the main technical recommendations for solutions that can be used in multi-family buildings. This table aims at being a tool that would facilitate decision-making for future project developers, to improve the quality and performance of buildings for increased sustainability.

The solutions are therefore detailed according to the phases of design, construction and maintenance, always considering the full life-cycle of the building and the different stakeholders and users involved. These solutions should deliver social, economic and environmental benefits.

Some key social aspects to consider are: availability of a formal workforce (legally employed), care in acquisition and manufacturing of materials and components, impact on the creation of "green" jobs. Actions should form incentive to expand the sustainability market (for instance, input managers and components industry).

To evaluate environmental benefits, impacts related to the inputs used over the life-cycle of the project will be assessed. The analysis of economic benefits should also consider the different phases of design, construction and operation/maintenance.

For each of the proposed solutions, several beneficiaries and users are concerned. These will be identified in the following section (section 4).

It is also important to highlight that the table presents potential solutions, but their applicability and impact will vary according to regional aspects, as well as cultural, social and economic aspects.

Table 6 is composed of 22 sub-tables, focused on the actions numbered below:

Solutions for energy efficiency:

1. Adoption of design strategies based on the Brazilian bioclimatic zoning
2. Solar water heating
3. Provision of energy-efficient appliances and equipment
4. Use of lining and/or radiant barriers/ insulation in roofing
5. Use of low absorptance roofing solution
6. Frames and shading of frames (windows)
7. Use of photovoltaic energy
8. Remote measurement of energy input
9. Natural shading
10. Green roof
11. Gas water heating
12. Appropriate ceiling height

Solutions for water demand and supply management:

1. Accessible shafts and systems, through hydraulic walls
2. Rationalized hydraulic systems
3. Individual measurement of cold and hot water
4. Control of flow and pressure
5. Water-saving equipment and appliances
6. Rainwater retention system
7. Rainwater harvesting system for landscape irrigation and washing of exterior areas
8. Rainwater harvesting for sanitary use
9. Greywater reuse system for sanitary use
10. Efficient landscaping

As shown above, twelve actions are proposed for energy efficiency, and ten solutions are proposed for rational water use (item 8 under energy efficiency solutions, for remote measurement of energy input, can also be applied to other types of inputs, such as water or gas).

For each solution, the table is divided in three parts, named design, construction and operation/maintenance. Each of those divisions was sub-divided in action; difficulty of implementation and availability of suppliers. The "action" describes the activities to be implemented.

Each item was rated to facilitate understanding. The levels of difficulty of implementation of a solution, in the phases of design, construction/implementation and operation/maintenance are defined as "low", "medium" and "high". A "low" rating means that there is little or no difficulty in implementation of the solutions (e.g. solution is available on the market and specialized workforce is available for such implementation). A "high" level of difficulty corresponds to the opposite: implementation is complex due to technical or cost difficulties, or even difficulties in access to the equipment.

Regarding the availability of material suppliers, installation options, and maintenance possibilities for the products or building, two levels were established: "inefficient" or "consolidated". "Inefficient" refers to a situation where products or workforce (depending on the item analyzed) are not available. "Consolidated" means that the solution is widespread on the market, and that products and services are available.

01	Solution:		ADOPTION OF DESIGN STRATEGIES ACCORDING TO THE BRAZILIAN BIOCLIMATIC ZONING
Implementation Variables			Verification of local characteristics of direct surrounding to evaluate the need for differentiated strategies besides those suggested by the Brazilian bioclimatic zoning.
DESIGN	Action		• Verify the bioclimatic zone of the project, available in NBR 15220-3 and in the manual for the Casa Azul label, developed by Caixa; • Verify necessary strategies for summer, and depending on the bioclimatic zone, for winter; • Study the best manner to adopt these design strategies through shape, location and orientation of buildings and areas (especially permanent areas), need and location of openings, etc; • Specify materials (components for walls and roofing) that comply with the parameters established by the NBR 15575 for buildings up to five floors and by the NBR 15220-3 for single-family residences.
	Level of difficulty		Low
	Availability of suppliers	Product	Consolidated
		Design	Insufficient
CONSTRUCTION	Action		Construct the building according to the requirements developed in design phase
	Level of difficulty		Low
	Availability of suppliers		Consolidated
OPERATION/ MAINTENANCE	Action		Instruct users through manual and training course to demonstrate the appropriate use of the residence, when bioclimatic strategies defined in the project phase have to be implemented.
	Level of difficulty		Low
	Availability of suppliers		Consolidated

02	Solution:		SOLAR WATER HEATING
Implementation Variables			Viability of technical solution with high system performance
DESIGN	Action		• Check level of sunshine of the location; • Check viability of positioning for the panels to the true North or maximum 30° east or west; • Check most appropriate installation according to building typology (single family or multi-family); • Check the necessary auxiliary heating equipment for improved performance: electric or gas, internal to the boiler or at consumption point, manual or automated; • Check minimum attained solar fraction between 60% and 80% with the appropriate area for panels and thermal reservoir; • Consider a consumption of 50L/person and 2 persons per room; • Observe maximum distances between the collector and the thermal reservoir, as well as between the reservoir and the consumption point, as well as necessary insulation of pipes; • Examine the need for anti-freeze substances in climates where winters are more severe; • Ensure individualized metering and detailed metering of individual consumption (hot/cold).
	Level of difficulty		Low for single-family buildings/ High for multi-family buildings
	Availability of suppliers	Product	Consolidated
		Design	Consolidated
CONSTRUCTION	Action		• Ensure individualized metering and detailed metering of individual water consumption; • Ensure the use of solar collectors rated level A or B by INMETRO, and thermal reservoirs labeled by PROCEL; • Ensure that installation is conducted by a Qualisol-certified company.
	Level of difficulty		High
	Availability of suppliers		Consolidated
OPERATION/ MAINTENANCE	Action		• Regularly clean panels; • In small multi-family buildings with individual heating systems, maintenance becomes individual.
	Level of difficulty		High
	Availability of suppliers		Consolidated

03	Solution:		PROVISION OF EFFICIENT EQUIPMENT AND APPLIANCES
Implementation Variables			• For social housing, deliver housing units with efficient appliances, considering at least refrigerators and roof ventilators in the living areas; • Possibility of personalizing action with the users to increase success probability. Focus (on delivery) on: 1. Refrigerators; 2. Roof ventilators; 3. Light bulbs; 4. Equipment for multi-family buildings' common areas; 5. Gas stove; 6. Other equipment (washing machine, microwaves, etc).
DESIGN	Action		In case roof ventilators are supplied for living areas, consider it in the electric design.
	Level of difficulty		Low
	Availability of suppliers	Product	Consolidated
		Design	Consolidated
CONSTRUCTION	Action		• Request electricity equipment labeled by PROCEL or level A of the PBE. Request gas equipment labeled by CONPET or level A of the PBE. Before defining equipment specifications, verify the efficiency and monthly energy consumption (in kWh) on the INMETRO website: http://www.inmetro.gov.br/consumidor/tabelas.asp; • Ensure the possibility of personal choice of appliances by users, especially for refrigerators. Partnerships will appliances providers may be established.
	Level of difficulty		Low
	Availability of suppliers		Consolidated
OPERATION/ MAINTENANCE	Action		If appliances are not provided at delivery, specify the importance of efficient appliances in the users' manuals, linking this choice with the reduction of electricity bills for users.
	Level of difficulty		Low
	Availability of suppliers		Consolidated

04	Solution:		USE OF INSULATION AND/OR RADIANT BARRIERS IN THE ROOF
Implementation Variables			• Determine the type of insulation to be used in the design based on the conducitivity and heat capacity required from the roofing, according to the bioclimatic zone and specific project needs; • Wood, PVC or plaster insulation provide lower weight and lower heat capacity; • Roof slabs have a greater weight and high heat capacity and are important when it is necessary to maintain systems that are above or below the roof; • Check the need for radiant/isolating barrier in the roofing.
DESIGN	Action		• Check NBR 15220-3 for single-family social housing units, or NBR 15575 for buildings up to 5 stories, to verify suitable roofing characteristics relating to conductance and heat capacity; • Radiant barriers such as blankets, stone wool or similar are suitable to increase the thermal resistance of the roof. They can be used as light insulation and should be used with roof slabs to avoid overheating of the unit in summer nights, as roof slabs have a high heat capacity and transmit the accumlated heat into the interior of the building; • Isolating blankets are suitable for various types of roof, especially lightweight roofing materials such as metal or fibre cement.
	Level of difficulty		Medium
	Availability of suppliers	Product	Consolidated
		Design	Consolidated
CONSTRUCTION	Action		If a single-sided aluminium insulation blanket is used, place the aluminium facing the interior and not towards the roof as is commonly done.
	Level of difficulty		Low
	Availability of suppliers		Consolidated
OPERATION/ MAINTENANCE	Action		Depending on the insulation type and material, conduct maintenance according to manufacturer/ supplier recommendations.
	Level of difficulty		Low
	Availability of suppliers		Consolidated

05	Solution:		USE OF LOW ABSORBANCE ROOFING
Implementation Variables			• Determine the type of insulation to be used in the design based on the conducitivity and heat capacity required from the roofing, according to the bioclimatic zone and specific project needs; • Wood, PVC or plaster insulation provide lower weight and lower heat capacity; • Roof slabs have a greater weight and high heat capacity and are important when it is necessary to maintain systems that are above or below the roof; • Check the need for radiant/isolating barrier in the roofing.
DESIGN	Action		• Check NBR 15220-3 for single-family social housing units, or NBR 15575 for buildings up to 5 stories, to verify suitable roofing characteristics relating to conductance and heat capacity; • Radiant barriers such as blankets, stone wool or similar are suitable to increase the thermal resistance of the roof. They can be used as light insulation and should be used with roof slabs to avoid overheating of the unit in summer nights, as roof slabs have a high heat capacity and transmit the accumlated heat into the interior of the building; • Isolating blankets are suitable for various types of roof, especially lightweight roofing materials such as metal or fibre cement.
	Level of difficulty		Medium
	Availability of suppliers	Product	Consolidated
		Design	Consolidated
CONSTRUCTION	Action		If a single-sided aluminium insulation blanket is used, place the aluminium facing the interior and not towards the roof as is commonly done.
	Level of difficulty		Low
	Availability of suppliers		Consolidated
OPERATION/ MAINTENANCE	Action		Depending on the insulation type and material, conduct maintenance according to manufacturer/ supplier recommendations.
	Level of difficulty		Low
	Availability of suppliers		Consolidated

06	Solution:		FRAMES AND SHADING
Implementation Variables			• Shading is required for all frames in bedrooms in brazilian bioclimatic zones 3 to 5 and if possible, in living areas; • Frames that do not allow complete opening of the blinds should not be specified in the design.
DESIGN	Action		• Check the size of openings for single-family housing units according to NBR 15220-3 and for buildings up to 5 stories according to NBR 15575; • Specify frames that are flexible and allow ventilation, shading and illumination; • For venetian blinds, specify light colours or colours suitable to the bioclimatic zone.
	Level of difficulty		Medium
	Availability of suppliers	Product	Insufficient
		Design	Consolidated
CONSTRUCTION	Action		• Guarantee good tightness in the installation of the frames; • Use specialized workforce for the installation.
	Level of difficulty		Low
	Availability of suppliers		Consolidated
OPERATION/ MAINTENANCE/	Action		For wooden frames, conduct protective maintenance every year or according to manufacturer's recommendations.
	Level of difficulty		Medium
	Availability of suppliers		Insufficient

07	Solution:		USE OF PHOTOVOLTAIC ENERGY
Implementation Variables			• Viability of positioning for panels, in relation to the area required, discounting possible shadow areas; • Economic viability depending on the potential energy generation and the financial investment; • For sites in urban areas, propose photovoltaic systems that are connected to the grid. For locations without access to the electric grid, propose isolated systems.
DESIGN	Action		• Integrate photovoltaic modules considering the location where the greatest possible level of radiation can be reached, whether on the roof, louvers or other elements, avoiding shadow areas; • Determine the level of radation that will reach the plane where the system is to be placed; • Check the nominal power being installed (in kWp), which should be estimated according to the percentage of electrical energy that it would supply for the unit; • Determine the amount of energy to be generated by the system; • Choose the type of photovoltaic module depending on the efficiency and available area. Modules with lower efficiency take up a larger area, while more efficient modules take up a smaller area, but are more expensive; • Choose inverters whose maximum input power is very close to the system's nominal power installed; • Determine the space required for the inverters.
	Level of difficulty		High
	Availability of suppliers	Product	Insufficient
		Design	Insufficient
CONSTRUCTION	Action		• Commission the installation to guarantee that everything is installed according to the specifications; • Carefully assemble panels; • Contract specialised photovoltaic energy workforce for electrical installation and assembly.
	Level of difficulty		High
	Availability of suppliers		Insufficient
OPERATION/ MAINTENANCE	Action		• Periodic washing of the modules, depending on the location; • Predict replacement of the inverters depending on their expected product life; • Conduct continuous automated monitoring of the systems to check whether the energy generation is within that estimated in the design phase.
	Level of difficulty		Low
	Availability of suppliers		Insufficient

08	Solution:		REMOTE METERING OF ENERGY INPUT
Implementation Variables			Important for all typologies.
DESIGN	Action		Consider final energy use metering in the scope of the electrical design.
	Level of difficulty		Medium
	Availability of suppliers	Product	Consolidated
		Design	Consolidated
CONSTRUCTION	Action		• PLC technology uses the existing electrical network structure and does not require new facilities; • Install the metering equipment.
	Level of difficulty		High
	Availability of suppliers		Consolidated
OPERATION/ MAINTENANCE	Action		• Gas reconnection should be done manually by a specialized technician when required; • Maintenance should be done on the exterior of the building.
	Level of difficulty		High
	Availability of suppliers		Low

09	Solution:		NATURAL SHADING
Implementation Variables			Need for shading of the building facade and of some parts of the building and/or of exterior spaces such as parking spaces or pedestrian walkways.
DESIGN	Action		Check building orientation in relation to the sun exposure and estimate the need for natural shading through elements such as trees, vines, etc; Indicate preference for native or other plants.
	Level of difficulty		Low
	Availability of suppliers	Product	Consolidated
		Design	Consolidated
CONSTRUCTION	Action		• Transplant larger trees, which produce efficient shading, to the work sites; • Carefully arrange plants according to species.
	Level of difficulty		Low
	Availability of suppliers		Consolidated
OPERATION/ MAINTENANCE	Action		• Larger trees (native or imported) require minimal maintenance, only inicial watering when planting; • Necessary maintenance should be conducted according to the individual characteristics of the species planted.
	Level of difficulty		Low
	Availability of suppliers		Consolidated

10	Solution:		GREEN ROOF
Implementation Variables			• Situations where it is necessary to leave roof slabs exposed for future extensions; • Places where frequent irrigation is not necessary to maintain grass and plants; • Roofing for environments where it is necessary to increase the thermal capacity while maintaining a high degree of comfort.
DESIGN	Action		• Define roof use in the initial phase of the project for compatibility with the structural project due to its weight; • Define type of roof, whether it should be grass or lighter structures for coverage only; • Define roof maintenance in the design and insert maintenance procedures in the drawing plans.
	Level of difficulty		Medium
	Availability of suppliers	Product	Insufficient
		Design	Consolidated
CONSTRUCTION	Action		• Careful waterproofing of the roof cover; • Correct specification of the grass and plants so roots will not reach the waterproof cover. Plants should be compatible with the local region and not require much maintenance or water; • If there is subsequent retention of rainwater in the green roof, increase the rate of filtering.
	Level of difficulty		High
	Availability of suppliers		Insufficient
OPERATION/ MAINTENANCE	Action		Periodical maintenance of plants and grass on the roof (cleaning, pruning and weeding).
	Level of difficulty		Medium
	Availability of suppliers		Insufficient

11	Solution:		GAS WATER HEATING
Implementation Variables			Prioritize if distribution network for natural gas is already in place.
DESIGN	Action		• Can be integrated as auxiliary equipment to the solar heating system, especially in multifamily buildings; • System must include a direct passage heater and a chimney (individual or collective) to supply heat to the showers; • For systems running on natural gas alone, showers must have reduced rates of water flow; • Check the appropriate pipe sizing to simultaneously supply all consumer end points; • Install water heaters in a protected area with adequate ventilation.
	Level of difficulty		Medium
	Availability of suppliers	Product	Consolidated
		Design	Consolidated
CONSTRUCTION	Action		• Install only direct passage heaters labelled by CONPET or level A or B of the INMETRO programme; • Technicians installing the heaters must comply with the Program QUALINSTAL GÁS; • If there are thermal reservoirs, they must be insulated; • Proper insulation of hot water piping; • Attention to adequate installation distances to optimize performance.
	Level of difficulty		Medium
	Availability of suppliers		Consolidated
OPERATION/ MAINTENANCE	Action		Inspect/replace the battery of the passage heater every 6-8 months or according to manufacturer's recommendations.
	Level of difficulty		Medium
	Availability of suppliers		Consolidated

12	Solution:		ADEQUATE CEILING HEIGHT
Implementation Variables			• In multi-family dwellings, check the maximum height allowed for the building according to the desired number of floors; • Higher celings improve thermal comfort in summer; • Lower ceilings improve thermal comfort in winter.
DESIGN	Action		• Consider adequate ceiling height at the beginning of the design; • Do not consider ceiling heights inferior to 2.40 m in low occupancy areas. In high occupancy areas consider ceiling heights equal or greater than 2.6 m, which allow for the use of ceiling fans; • Check that the extra ceiling height provides space to increase opening areas and allows for ventilation or lighting traps, if adequate to the project and the climatic region.
	Level of difficulty		Low
	Availability of suppliers	Product	Consolidated
		Design	Consolidated
CONSTRUCTION	Action		Ensure adequate construction and masonry
	Level of difficulty		Low
	Availability of suppliers		Consolidated
OPERATION/ MAINTENANCE	Action		None
	Level of difficulty		Low
	Availability of suppliers		Consolidated

WATER MANAGEMENT

01	Solution:		ACCESSIBLE SHAFTS AND SYSTEMS THROUGH HYDRAULIC WALLS
Implementation Variables			• Type of internal sealing; • Project standard procedures.
DESIGN	Action		• Integrated conception of hydraulic building systems, optimizing system layout and reducing the number of connections; • Descriptive data-sheet including hydraulic kits and components, execution details and information on operation and maintenance; • Greater standardization of sanitary environments.
	Level of difficulty		Low
	Availability of suppliers	Product	Medium
		Design	High
CONSTRUCTION	Action		• Integrated installation of hydraulic building systems, optimizing system layout and reducing the number of connections; • Descriptive data-sheet including hydraulic kits and components, execution details and information on operation and maintenance; • Greater standardization of sanitary environments.
	Level of difficulty		Low
	Availability of suppliers		Low
OPERATION/ MAINTENANCE	Action		• Professional training; • Establish regular routines.
	Level of difficulty		Low
	Availability of suppliers		Low

02	Solution:		RATIONALIZED HYDRAULIC SYSTEMS
Implementation Variables			• Type of internal sealing; • Project standard procedures.
DESIGN	Action		• Design hydraulic building systems with a rationalized layout, preferably using end-to-end systems, and high reduction of the number of connections; • Provide operation and maintenance details.
	Level of difficulty		Low
	Availability of suppliers	Product	High
		Design	High
CONSTRUCTION	Action		• Careful installation, respecting materials' specifications as defined in technical standards and manufacturers' manuals; • Professional training.
	Level of difficulty		Medium
	Availability of suppliers		Low
OPERATION/ MAINTENANCE	Action		• Professional training; • Establish regular routines.
	Level of difficulty		Low
	Availability of suppliers		Low

03	Solution:		INDIVIDUAL METERING OF COLD AND HOT WATER
Implementation Variables			• Project standard procedures; • Requirements of local utilities company; • Type of water heating system.

DESIGN	Action		• Use the probabilities method to define the size of meters;
			• Check standards and norms of the local utility company;
			• Select the technology that will be applied and verify its consistency with the requirements of the local utility company;
			• Check load losses caused by meters and potential requirement for water closing valves;
			• The design should state the metering unit;
			• The choice of the type of water heating system determines the standard input consumption:
			  • For an individual system with gas passage-heater (instantaneous), only meter cold water;
			  • For an individual system of gas water heating through accumulation, meter both cold water and cold water used for supply of the accumulation heater;
			  • For a central gas water heating system, cold and hot water are metered separately;
			  • For electric showers, only meter cold water;
			  • For solar heating systems with electric shower support, meter cold and hot water;
			  • For individual solar heating systems with electric showers, meter cold water;
			  • For collective solar heating systems with electric showers, meter cold and hot water;
			  • For solar water heating, supported by a gas passage-heater, meter cold and hot water;
			  • For solar water heating, supported by a gas accumulation heater, meter cold water and cold water supplying the heater.

	Level of difficulty		Medium
	Availability of suppliers	Product	High
		Design	Medium

CONSTRUCTION	Action	• Respect design specifications and technical norms of the local utility company; • Ensure correct positioning of the meters to guarantee accurate metering; • Select an appropriate metering technology; • Provide users with the possibility to access the metering equipment.
	Level of difficulty	Low
	Availability of suppliers	Medium
OPERATION/ MAINTENANCE	Action	• Professional training; • Establish regular maintenance routines for the metering system, to ensure quality of the collected data.
	Level of difficulty	Low
	Availability of suppliers	Low

04	Solution:		FLOW AND PRESSURE CONTROL
Implementation Variables			• Height of the project; • Project layout; • Availability of individual metering.
DESIGN	Action		• Require pressure reduction valves if the pressure exceeds 40 mWc; • Require flow restrictors at the point-of-consumption; • Use probabilities calculations to calculate flow and appropriately size meters and water pipes.
	Level of difficulty		Low
	Availability of suppliers	Product	Medium
		Design	High
CONSTRUCTION	Action		• Install pressure reduction valves when the pressure exceeds 40 mWc; • Install flow reduction devices at the point-of-consumption.
	Level of difficulty		Low
	Availability of suppliers		Medium
OPERATION/ MAINTENANCE	Action		• Establish regular preventive maintenance routines (calibration of pressure gauges, cleaning of Y filters); • Train water managers in the buildings.
	Level of difficulty		Medium
	Availability of suppliers		Medium

05	Solution:		WATER-SAVING EQUIPMENT AND APPLIANCES
Implementation Variables			Project standard procedures.
DESIGN	Action		• Specify the equipment and appliances in the design phase, and make sure the selected options are included in PBQP (Brazilian Programme for Housing Quality and Productivity); • Stimulate the use of "dual flush" devices, water saving faucets, faucets with restricted access for outside use, showers with flow restrictors and flow restrictors for faucets.
	Level of difficulty		Medium
	Availability of suppliers	Product	Medium
		Design	Medium
CONSTRUCTION	Action		• Install the equipment complying with manufacturers' requirements; • Use products and components that comply with Brazilian technical norms.
	Level of difficulty		Low
	Availability of suppliers		Medium
OPERATION/ MAINTENANCE	Action		• Provide the tools required for future maintenance; • Provide references of places to purchase spare parts to future residents and managers; • Establish regular preventive maintenance routines; • Train building water managers.
	Level of difficulty		Medium
	Availability of suppliers		High

06	Solution:		RAINWATER RETENTION SYSTEMS
Implementation Variables			• Bioclimatic zone; • Compliance with legislation; • Project standard procedures.
DESIGN	Action		• Comply with the piscininha law (law n° 12.526/2007) to define the dimensions of the reservoir; • Specify in data-sheet the requirements for operation and maintenance.
	Level of difficulty		Medium
	Availability of suppliers	Product	Medium
		Design	Medium
CONSTRUCTION	Action		• Install the water collection system according to project specifications; • Use products and components that comply with Brazilian standards.
	Level of difficulty		Medium
	Availability of suppliers		Medium
OPERATION/ MAINTENANCE	Action		• Provide tools required for future maintenance; • Establish regular preventive maintenance routines; • Training building water managers.
	Level of difficulty		Medium
	Availability of suppliers		Medium

07	Solution:		RAINWATER HARVESTING SYSTEMS FOR LANDSCAPE IRRIGATION AND WASHING OF EXTERIOR AREAS
Implementation Variables			• Bioclimatic zone; • Availability of local infrastructure and space for collection and storage; • Project standard procedures.
DESIGN	Action		• Calculate the dimensions of the exclusive tank using standard NBR 15527/07; • Design the rainwater roof collection system (channels, pipes and connections); • Select the type of water treatment and coloring; • Specify the use of restricted access faucets at the points of consumption; • Provide the signalization design.
	Level of difficulty		High
	Availability of suppliers	Product	Medium
		Design	Medium
CONSTRUCTION	Action		• Install different cold water distribution systems for potable and non-potable water, avoiding cross-connections and following the requirements of ABNT NBR 5626/98; • Consumption points, as for instance a garden faucet, should be identified with a warning sign stating “non-Potable Water” and include an illustration for illiterates or children; • Mark water sources offering non potable water, e.g. garden faucets, with a sign indicating “non-potable water” as well as with an illustrative sign, which can be understood by people who cannot read and children; • Two different water tanks (one for potable water and one for non-potable water) should be used; • The installation of faucets with restricted access is recommended.
	Level of difficulty		High
	Availability of suppliers		Medium
OPERATION/ MAINTENANCE	Action		• Provide training to the users and train a water manager for the building/ condominium; • Periodically perform a physicochemical analysis of the water; • Establish preventive maintenance routines in cooperation with a qualified company or professional.
	Level of difficulty		High
	Availability of suppliers		Medium

08	Solution:		RAINWATER HARVESTING SYSTEMS FOR SANITARY USE
Implementation Variables			• Bioclimatic zone; • Availability of local infrastructure and space for collection and storage; • Project standard procedures.
DESIGN	Action		• Calculate the dimensions of the exclusive tank using standard NBR 15527/07; • Design the rainwater roof collection system (channels, pipes and connections); • Design the hydraulic building system for potable and non potable water; • Select the type of water treatment; • Coloring for alternative water sources; • Design signalling requirements; • Provide a data-sheet describing in details the systems' mode of operation, type of materials to be used and execution requirements; • Register the system through a Technical Responsibility Note (ART) and define responsibility terms.
	Level of difficulty		High
	Availability of suppliers	Product	Medium
		Design	Medium
CONSTRUCTION	Action		• Require verification of the installation of the building system by a professional technician to guarantee conformity with design requirements before closing the walls; • Identify and signal non-potable water hydraulic systems to avoid contamination risks (if required, use different materials); • Signal non potable water sources, e.g. garden faucets, with a sign indicating "non potable water" as well as with an illustrative sign, which can be understood by people that cannot read and children; • Provide professional training to the construction team; • Verify and submit the Technical Responsibility Note.
	Level of difficulty		High
	Availability of suppliers		Medium-High
OPERATION/ MAINTENANCE	Action		• Provide training to the users; • Train a water manager for the building(s); • Control interventions in residential units to avoid potential risks related to cross-connections; • Execute periodically a physicochemical analysis of the water; • Establish preventive maintenance routines in cooperation with a qualified company or professional
	Level of difficulty		High

09	Solution:		GREYWATER REUSE SYSTEMS FOR SANITARY USE
Implementation Variables			• Bioclimatic zone; • Availability of local infrastructure and space for collection and storage; • Project standard procedures.
DESIGN	Action		• Calculate the dimensions of the exclusive tank (comply with international codes and standards); • Design the hydraulic building system for potable and non potable water; • Select the appropriate treatment for the water; • Colouring for alternative water sources; • Design signalling system; • Provide a detailed description of the functions of the system, materials used and use guidelines.
	Level of difficulty		High
	Availability of suppliers	Product	Medium-High
		Design	Medium-High
	Availability of suppliers		Medium-High
OPERATION/ MAINTENANCE	Action		• Provide training to the users; • Train a building water manager; • Control interventions in residential units to avoid potential risks related to cross-connections; • Execute periodically a physicochemical analysis of the water; • Establish preventive maintenance routines in cooperation with a qualified company or professional .
	Level of difficulty		High
	Availability of suppliers		Medium-High

10	Solution:		EFFICIENT LANDSCAPING
Implementation Variables			• Bioclimatic zone; • Availability of local infrastructure and space for collection and storage; • Project standard procedures.
DESIGN	Action		• Select carefully the type of pavement, soil and vegetation; • If possible, design an irrigation system with alternative water sources; • Automate or propose the use of the irrigation system at night to reduce water loss by evaporation; • Elaborate the signalling design; • Required the use of restricted access faucets; • Sectorize water consumption; • Provide a detailed description of the functions of the system, materials used and use guidelines.
	Level of difficulty		Medium
	Availability of suppliers	Product	Medium
		Design	Medium
CONSTRUCTION	Action		• Implement the irrigation system according to the design requirements, including sectorized water consumption; • Signal non potable water sources, e.g. garden faucets, with a sign indicating “non potable water” as well as with an illustrative sign, which can be understood by people that cannot read and children.
	Level of difficulty		Medium-Low
	Availability of suppliers		Medium-Low
OPERATION/ MAINTENANCE	Action		• Train users and system operators (if required, cleaning team); • Establish preventive maintenance and operation routines in cooperation with a qualified company or professional.
	Level of difficulty		Medium-Low
	Availability of suppliers		Medium

4 Development of a project guide based on the technical evaluation of alternative solutions

In order to facilitate the selection of sustainability solutions, a matrix of actions related to energy and water was developed (Tables 8 and 9 respectively).

To enable the use of this matrix as a practical tool, solutions are rated according to their efficiency level for several types of building projects that include social housing as well as residential buildings of medium and high standard.

Each solution is assessed according to implementation and operation/ maintenance costs, as well as expected benefits. The objective of this table is to raise awareness of the importance of considering the use life of the building to analyze and choose the appropriate solutions. In fact, the most important costs of a residential building are incurred during the operation phase and not in construction or design.

A ranking scale was created for costs and benefits, divided in three levels: high, medium, and low. Although it is difficult to quantify the exact costs and benefits, as well as the exact ranking for each level, the 3-level classification was adopted to facilitate evaluation of sustainability solutions and assist in decision making. For instance, it would be unviable to choose a solution that has a high installation and maintenance cost, and low expected benefits at social, economic and environmental level. On the other hand, a certain solution that would deliver relevant benefits with medium costs could deliver a medium-term financial return on investment, according to a detailed analysis conducted by the developer. The tables provide preliminary guidelines for the developer, so that he/she can be aware of the potential solutions and have a general idea of the benefits of a solution compared to its costs, and the relative cost of one solution compared to another.

Table 7 – Brazilian social strata, 2009 census (Source: adapted from Oscar, 2010)

Class	Family income (in minimum wages)	% of the population (2009)
A	Above 20	5,7
B	From 10 the 20	9,8
C	From 3 to 10	49,7
D	From 1 to 3	27
E	From 0 to 1	6,8

It is important to highlight that this ranking was developed for the specific region of São Paulo in Brazil. Local, cultural, social and economic specificities can significantly influence the order in which solutions were ranked.

In Tables 8 and 9, for the "Building Type", S refers to single-family buildings, while M refers to multi-family residences. In terms of building project types, divided in SH (social housing), medium and hight, these refer to the Brazilian residential standards. In Brazil, the social stratification is divided as shown below.

According to Oscar (2010), this stratification does not necessarily provide an accurate picture to identify which families are included in which class, since there is no official definition. A Brazilian Association of Research Firms (Associação Brasileira de Empresas de Pesquisas -Abep) uses what is called the "Brazil Criterion", which is based on property and education level. However, most surveys only consider family income. The social housing program "My House My Life (Minha Casa Minha Vida), developed through a partnership between the Federal Government and Caixa Econômica Federal, gives priority to families living with maximum 3 minimum wages. The program does consider families making up to 10 minimum wages, but among these families, those making less than 6 minimum wages are given priority to[3]. For the first category, that would correspond, according to Table 7, to classes D and E, two types of houses are proposed by the programme: individual house of 35 m^2 and apartment of 42 m^2. For class C, no specific typology is defined.

Therefore, in tables 8 and 9, social housing relates to families included in classes D and 3, while the "medium" category refers to class D, and the "high" category refers to classes A and B.

3 In: http://downloads.caixa.gov.br/_arquivos/habita/mcmv/CARTILHACOMPLETA.PDF

In terms of efficiency level, the solutions were inserted in the table according to a “high”, “medium” or “low” ranking. Solutions that show a low efficiency level are usually not very well received and there is no guarantee of the success of the action. However, those ranked as highly efficient are the most recomended solutions, as they present an actual return on investment through their high social, economic and environmental benefits.

It is important to note that the considered benefits are assessed as relative benefits, comparing the solution to a business-as-usual solution.

Table 8 – Matrix of actions for energy efficiency and thermal comfort

EFFICIENCY LEVEL		TYPE OF SOLUTION	BUILDING PROJECT TYPE						COSTS		BENEFITS		
			SH		MEDIUM		HIGH						
			U	M	U	M	U	M	IMPLEMENTATION	OPERATION	SOCIAL	ECONOMIC	ENVIRONMENTAL
HIGH	01	Use of design strategies adapted to the Brazilian bioclimatic zones	X	X	X	X	X	X	Low	Low	High	High	High
	02	Solar water heating	X		X		X		Medium	Low	High	High	High
		Solar water heating		X		X		X	High	High	Medium	Medium	High
	03	Provision of efficient equipments and appliances: refrigerator	X	X					Medium	Low	High	High	High
		Provision of efficient equipments and appliances: roof ventilators	X	X	X	X			Low	Low	Medium	High	High
	04	Use of lining and/or radiant barriers/ insulation for the roof	X	X	X	X	X	X	Medium	Low	High	High	High
	05	Use of low absorbtance roofing materials	X	X	X	X	X	X	Medium	Medium	High	High	High
	06	Windows and shading	X	X	X	X	X	X	Medium	Low	High	High	High
	07	Photovoltaic energy (grid-connected)			X	X	X	X	High	Low	Medium	High	High
		Photovoltaic energy (non grid-connected)	X						High	Low	High	High	High
MEDIUM	08	Remoting energy input metering	X	X	X	X	X	X	Medium	Medium	Low	Medio	Medio
	09	Natural shading	X	X	X	X	X	X	Medium	Medium	Low	High	High
	10	Green roof	X	X	X	X	X	X	High	Medium	Low	Low	High
	11	Gas water heating		X		X		X	Medium	Low	Medium	Medium	Medium
LOW	12	Provision of efficient equipments and appliances: other appliances		X		X		X	Medium	Low	Low	Medium	Medium
	13	Appropriate ceiling height	X	X					Low	Low	Low	Low	Medium

Table 9- Matrix of actions for water consumption reduction

EFFICIENCY LEVEL		TYPE OF SOLUTION	BUILDING PROJECT TYPE						COSTS		BENEFITS		
			SH		MEDIUM		HIGH						
			U	M	U	M	U	M	IMPLEMENTATION	OPERATION	SOCIAL	ECONOMIC	ENVIRONMENTAL
HIGH	01	Individual metering		X					Medium	Medium	High	High	High
	02	Individual metering				X		X	High	Low	High	High	High
	03	Water-saving fixtures	X	X	X	X	X	X	Low	Low	High	High	High
	04	Accessible shafts	X	X	X	X	X	X	Medium	Medium	Medium	High	Medium
	05	Rationalized building systems	X	X	X	X	X	X	Medium	Medium	Medium	High	Medium
	06	Flow control	X	X	X	X	X	X	Low	Low	Medium	Medium	Medium
	07	Pressure control				X		X	Medium	Medium	Medium	Medium	Medium
LOW	08	Rainwater harvesting		X					Medium	Medium	Med-Low	Low	Med-Low
	09	Rainwater harvesting				X		X	Medium	Low	Med-Low	Low	Med-Low
	10	Rainwater harvesting			X		X		Medium	Medium	Med-Low	Low	Med-Low
	11	Rainwater harvesting for washing of outdoor areas	X		X		X		High	Medium	Medium	Low	High
	12	Rainwater harvesting for washing of outdoor areas		X					Medium	Medium	Medium	Low	High
	13	Rainwater harvesting for washing of outdoor areas				X		X	Medium	Low	Medium	Low	High
	14	Rainwater harvesting for sanitary use	X		X		X		High	High	Low	Low	Medium
	15	Rainwater harvesting for sanitary use		X					High	High	Low	Med-Low	Medium
	16	Rainwater harvesting for sanitary use				X		X	High	High	Low	Med-Low	Medium
	17	Greywater reuse for sanitary use				X		X	High	High	Medium	Medium	Medium
	18	Greywater reuse for sanitary use			X		X		High	High	Medium	Medium	Medium
	19	Efficient landscaping	X	X	X		X		Low	Low	Medium	Medium	Medium
	20	Efficient landscaping				X		X	Medium	Medium	Medium	Medium	Medium

Conclusion

Several technical and technological solutions have been assessed in this report, with the purpose to verify parameters for insertion of these solutions in the phases of design, construction and operation/maintenance, highlighting also risks associated with the implementation of these actions. The final project guide presents the sustainable solutions that could be used for social housing, ranked according to their efficiency, costs, and benefits.

Expected benefits through solutions for rational water use:

- Savings generated by the reduction of water consumption;
- Savings generated by the reduction of wastewater;
- Subsequent savings of other inputs such as energy and chemical products;
- Reduction of operation and maintenance costs for building hydraulic systems and equipments;
- Increase in water availability;
- Aggregation of product value;
- Improvement of company's image - social responsibility.

Expected benefits through solutions for energy efficiency:

- Savings generated by the reduction of electricity consumption;
- Energy autonomy in areas missing urban infrastructure (namely through photovoltaic energy);
- Increase comfort in showers (solar and gas heaters);
- Thermal comfort in buildings;
- Users' safety (remote metering of inputs);
- Reduction of heat-island effects (natural shading);
- Aggregation of product value;
- Improvement of company's image - social responsibility.

Choosing the best solution

There is no better or worse solution in a real context, as the choice of solution is based on project requirements, including site of construction, access to public water and sewage networks, availability of investment capital and return on investment rate (short, medium or long term).

Some solutions such as solar heating and individual metering have been proven to have a high level of efficiency based on previous experiences, with medium installation costs and high benefits. On the other hand, rainwater harvesting for sanitary uses has a high cost of intallation, and low to medium benefits for social housing, leading to think that it may not be the most appropriate solution at the moment for developers searching for a short return on investment time. However, the system can have positive impacts in reducing the consumption of potable water.

Recommendations

We can highlight that the solutions brought forward can contribute to the creation of green jobs in the construction industry, and have an impact on the development of new work opportunities in the countries. Furthermore, the promotion of sustainable solutions can be an incentive to the development of new materials and technologies for civil construction, based on environmental sustainability criteria.

The next step of this project will be to create a methodology to evaluate the solutions presented in this report after occupancy. This analysis would allow to better evaluate the impacts of the solutions over the different life cycle phases of the building, and over its entire life cycle, with particular emphasis on user acceptance and awareness-raising. Some of the solutions are currently being implemented by CDHU in its Program for Socio-Environmental Recuperation of Serra do Mar and Sistema de Mosaicos in the Mata Atlântica. The impact of these solutions and their acceptance will be monitored and evaluated.

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For more information, contact:
UNEP DTIE
Sustainable Consumption and Production Branch
15 Rue de Milan
75441 Paris CEDEX 09
France
Tel: +33 1 4437 1450
Fax: +33 1 4437 1474
E-mail: unep.tie@unep.org
www.unep.fr/scp/sun

www.unep.org
United Nations Environment Programme
P.O. Box 30552 Nairobi, Kenya
Tel.: ++254 (0) 20 762 1234
Fax: ++254 (0) 20 762 3927
Email: uneppub@unep.org

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This publication is the 3rd and last issue 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.
During the project, experts conducted an initial assessment of the status of social housing in Brazil, and subsequently reviewed previous initiatives aimed at integrating sustainable solutions in social housing projects. Based on this assessment and consultation with local stakeholders, this report provides a summarized assessment of several sustainable technologies and alternatives that could be applied to social housing projects in São Paulo. The report provides an analysis of costs, benefits, and efficiency of the alternative solutions selected to improve the sustainability performance of social housing units.
Priority was given to sustainable options that encourage rational use of water and lead to a reduced energy consumption without a decrease in comfort for the users. The classification provided in this report aims at facilitating the evaluation and selection process for sustainable solutions. Preliminary guidelines allow the entrepreneur to identify the types of solutions available on the market and understand the relative cost and impact of each type of solution compared to the other.

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