Aspects of Sustainable Construction in Brazil and Public Policy Promotion

Subsidies for Promoting Sustainable Construction

CBCS
Conselho Brasileiro de Construção Sustentável

PNUMA

Ministério do Meio Ambiente

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"This publication is the result of work undertaken by the CBCS (Brazilian Sustainable Construction Council) in partnership with the Ministry of the Environment and with UNEP (United Nations Environment Programme), in dialogue with entities that represent the sector.

This document is the product of years of reflection by the CBCS's Water, Materials and Energy Committees and its preparation involved contributions from some 40 people from different entities, in addition to the 381 people who took part in the opinion survey. It presents an integrating and multidisciplinary view of the topics and initially proposes guidelines that focus on water, energy and materials, although in the future these may be expanded to include other areas. In this participatory data collection process the information and experiences and the union of partners, academics, entity representatives and professionals who are active in the market were factors that determined the success of the project.

CBCS believes that this initiative strengthens its mission of spreading knowledge and good practices for expanding the sustainability of the construction sector, emphasizes the importance of structuring public policies and encourages the evolution of the whole of the production chain. The result is work that presents a reflection on the current conditions in the sector with regard to the topics mentioned above. It points out the bottlenecks and challenges and brings together a series of references and recommendations that can add the construction sector's contribution to the process of sustainable development in Brazil."

Carlos Eduardo Garrocho de Almeida
Chairman of the Board
Brazilian Council for
Sustainable Construction

"The United Nations Education Programme (UNEP) understands that mankind urgently needs to change its consumption and production patterns and it supports any actions that favor substantial progress in this direction. This publication presents the result of an initiative that has huge potential for influencing Brazilian production standards, by indicating ways of reducing the tremendous impact of construction, an activity that demands large amounts of raw materials and generates great amounts of waste.

Through the studies that are reported in this paper, UNEP, the Ministry of the Environment and CBCS offer information for preparing a national sustainable construction policy, which is in line with the priorities launched by the Action Plan for Sustainable Production and Consumption in Brazil."

Denise Hamú Marcos de La Penha
UNEP representative in Brazil

"The search for sustainability in the construction sector is a huge challenge. It involves the whole world, but above all countries like Brazil, which is still experiencing an on-going urbanization process, while at the same time having to face an enormous housing shortage, a legacy of the country's social inequality. In this context, sustainable construction is an imperative for ensuring a balance between protecting the environment, making economic growth feasible throughsocial inclusion and promoting environmental justice where it is most urgently needed, in our cities, where the most underprivileged live under precarious housing conditions. In this sense, the scale of the challenge is even greater when it becomes essential to extend this effort to the constructed and urban environment in order to ensure quality of life on a sustainable basis.

This publication is the result of a multidisciplinary and joint effort between academia and the public and private sectors in support of the second cycle of the Sustainable Production and Consumption Plan (PPCS). Its ambition is to mobilize stakeholders to debate the constitution of a future national strategy for promoting sustainable construction that needs to be expressed in a more ample and systemic way in the various sector policies, the object of attention of which is the constructed and urban environment. This is, therefore, an environment initiative that is a task for everybody. Tt implies, at the same time, clean air, renewable energy, quality water, adequate sanitation, transportation services and decent dwellings as a right for all."

Izabella Mônica Vieira Teixeira
State Minister of the Environment

Executive Summary

The study entitled "Aspects of Sustainable Construction in Brazil and Public Policy Promotion" is an attempt to organize a diagnosis of the current state of construction. It is intended as support for providing guidance for future public policies that can contribute towards directing the practices needed for a more sustainable construction industry in a technical and objective manner. The scope that was defined for this work is concentrated on three major areas in construction: water, energy and materials. The approach taken by the work includes priority lines in the constructed environment: buildings and systems, with a focus on demand. Information taken from a virtual survey involving sector professionals was used when including the demands of the chain.

The objective of the first stage of the project was to understand the actions of the agents involved in the construction sector, along with their needs and difficulties. To this end, a survey was proposed that consulted sector professionals. As defined in the scope of the work, the survey sought information about three areas: energy efficiency; the rational use and management of water; and the selection and destination of materials in the constructed environment. The purpose of consulting professionals was to identify the bottlenecks and the demand that serve as the basis for the proposed actions.

Due to the number of respondents to the survey, which was several times greater than expected, the first conclusion drawn emphasized the importance of having a communication channel for listening to the sector's demands and needs. In analyzing the survey data it became clear that some demands are common to the three areas studied, in other words, they are sector needs. Four lines of action were indicated, which will be dealt with in detail in the specific reports: (1) lack of knowledge, the need for campaigns for enlightening the population, and demand for a greater degree of technical training for those involved; (2) the need to develop specific tools; (3) the need to create incentives and lines of credit; and (4) demand for specific legislation and regulations.

The main focus of the Water theme is on demand management in buildings, as a permanent instrument for ensuring consumption indicators are compatible with the region and the types of use and user, the aim being to use water efficiently.

This document shows how vulnerable the water situation is in Brazilian urban centers and indicates the need for establishing measures that guarantee a balance between the supply and demand for water, the quality of whch is suitable for the use to which it is being put. This is a condition for ensuring that these urban centers do not become economically and socially unviable. From the viewpoint of water demand, these actions are of an institutional, technological, quality and sustainability nature and for raising professional awareness and increasing professional training, which taken together can help reduce current consumption levels.

According to the Brazilian data presented in this document, water consumption in our urban centers is growing and if the tendency of the last few years continues, the capacity to supply water to these centers will not be sufficient to meet the needs of the population, industry, and irrigation, which are the main consumers.

With their focus on supplying the population, the studies and research that have been carried out show that the amount of water supplied is greater than the amount necessary for the adequate performance of consumer activities. This situation arises, among other reasons, because of the inappropriate operation and inadequate maintenance of water systems in buildings. A significant part of the water that supplies buildings is discarded without ever having been used, because it is either lost or wasted.

An efficient use of water in buildings will significantly reduce the demand for water for supplying the population, which needs enlightenment and technical support for achieving consumption indicators that are compatible with the various types of uses and to avoid adopting solutions that place public health at risk.

The existing institutional programs for managing water demand in order to reduce water consumption in buildings must be updated, expanded and implemented connecting the public and private sectors.

Component and service companies can be encouraged to take part in projects related to the efficient use of water through tax or tariff incentives.

The introduction of programs for substituting and adapting water products and for modernizing water systems in buildings for the efficient use of water will help eliminate the loss and waste caused by outdated equipment and improve pressure and flow control. In addition systems need to be installed for measuring consumption in order to make it feasible to manage demand better.

The strengthening and expansion of quality programs in the construction products and services sector, with a special focus on water systems in buildings, will help fight non-compliance with current standards and legislation, which will guarantee the quality of the products and services supplied to the population.

This document in no way exhausts the subject, but presents Brazilian and international programs and practices for the efficient use of water. It also puts forward 25 recommendations, whose objective is to support the definition of public policies that will encourage the efficient use of water in buildings in urban centers.

Energy consumption in buildings in Brazil has grown rapidly, due in part to the increase in the standard of comfort and the services offered in buildings. Recent peaks in demand and high construction rates – buildings that are ever larger and more complex – highlight the urgency there is in increasing energy efficiency right away, since the systems now being installed will be consuming energy over the next few decades. At the same time, the electricity matrix is becoming increasingly “dirty”, with greater emissions of greenhouse gases resulting from power generation, and the cost of energy is increasing; both these trends are being intensified over the short-term because of the recent rainfall shortage.

Rational energy use is considered internationally as being the “first fuel”, the best opportunity for reducing costs and the impact caused by energy generation and also for reducing the need for new transmission facilities. If the sector is treated with priority and urgency, there are various surveys, case studies and exemplary policies available that can be assessed and proposed for application in Brazil.

Rational energy use is a great opportunity in Brazil. The role of public policies will be essential for overcoming barriers and implementing programs. It is important to have a holistic strategic vision for the sector, such as, through the creation of a Brazilian Energy Efficiency Agency to prioritize, implement, monitor and evaluate programs.

Based on Brazilian and international surveys, a list of 27 priority policies and actions for improving sustainable energy use in the constructed environment has been identified. The current PBE Edifica Program must be supported and strengthened to realize all its potential for reducing consumption. It must also be complemented by the introduction of an assessment and certification program of the operational energy performance of buildings when in use. The retrofitting and rehabilitation of existing buildings must also be encouraged.

Training for area professionals is a key issue and must include strengthening technical institutions and improving university syllabuses.

INMETRO's PBE labeling must be strengthened and expanded to cover other areas and types of equipment. Minimum levels must also be periodically increased. This is most urgent in the air conditioning area, where minimum levels in Brazil are very much lower than the international equivalents, even when we compare them with those of developing countries. The purchasing power of large social housing programs must be used to stimulate and capacitate the construction industry to improve construction standards, adopt solar heating and use micro-generation.

The diagnoses and recommendations presented in this report have important potential for immediate and future reductions in energy consumption, provided the continuous improvement of services and the comfort of people in the constructed environment are always taken into consideration.

The building materials chain consumes approximately half of the raw materials extracted from nature. This is a conglomeration of various production chains, comprising companies of different sizes with a wide variety of technical, managerial and economic skills. Each sector in the chain has a specific environmental and social agenda.

Fiscal, quality, environmental and labor-related informality is always present and reduces the effectiveness of public policies. An extreme example of this is the native wood production chain. Policies that increase costs for the formal sector may increase the informal market sector. An alternative is to adopt policies that create economic benefits for companies and eco-efficient solutions. Combatting informality is a condition for introducing policies aimed at sustainability. The PBQP-H has a methodology for combatting informality that could be expanded and adapted to include environmental aspects. The retail area needs to commit to fighting informality. Policies aimed at regulating the disclosure of environmental licensing information would allow consumers to help fight environmental informality.

The Life Cycle Analysis (LCA), the most suitable tool for decisions based on environmental aspects, is complex for a sector in which there is a large number of small companies and where each project is a prototype. International construction standardization already uses an LCA of reduced scope. Data from the Brazilian market show that manufacturers exercise an enormous influence on the environmental impact of products: in most practical situations the most important decision has to do with selecting the supplier. As a consequence it is essential to introduce a Product Environmental Declaration that is also accessible to small and medium-size companies.

The proposed Modular LCA, which was forwarded to the PBACV by the ABRAMAT/FIESP-Deconcic materials' coordination area, is in line with international standardization and is sufficiently simple to encourage small and medium-size companies to take part in the Product Environmental Declaration program. It can also be expanded to be complete in its scope, thus generating a benchmark for the sector and a greenhouse gas inventory as added benefits.

Reducing the consumption of raw materials is a priority. Promoting the industrialization of construction will allow for a reduction in losses and, as a consequence, the environmental impact of construction. It will also allow for a reduction in the waste generated in construction. Sustainability depends on innovation. The creation of a program for encouraging eco-innovation has significant potential for producing an environmental return and a gain in the industry's competitiveness.

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Presentation

The study entitled "Aspects of Sustainable Construction in Brazil and Public Policy Promotion" tries to present a diagnosis of the current state of construction as information for proposing guidance for the future creation of public policies aimed at sustainable construction.

This document does not intend to provide a once and for all analysis, but to initiate a complex and rich discussion. It was the result of a concentrated effort by the large group of professionals who were involved in preparing it and in consultations about it. It was also able to rely on the accumulated knowledge of the Thematic Committees of the Brazilian Sustainable Construction Council (CBCS), which involved both associates and non-associates, companies, academics, entities and representatives from state bodies, the intention being to launch new ideas and open up the debate regarding the actions needed for structuring the sector that will receive state policy incentives for evolving the theme of sustainability in construction.

The CBCS enthusiastically accepted the task and the challenge of developing an interpretation of sustainability in Brazilian construction in a little under 60 days. In addition to the extensive research it carried out, the CBCS is delivering this material in the expectation that it will provoke systematic debate in the sector that will lead to the matter being looked at in greater depth and will encourage complementary studies on various fronts.

Many initiatives contribute towards sustainability: institutional actions, technological innovation, resource planning and management, raising the awareness of the population and professional training. In this sense public policies can help direct practices if they are agreed upon and introduced in production sectors in an assertive way. We believe there is great potential in Brazil for creating a structured national policy program aimed at promoting sustainable construction. This policy would add to global initiatives for more sustainable development.

In the CBCS point of view, advancing sustainability in the construction sector implies a series of systemic actions that must be adopted by all the agents that constitute the construction chain, by government and by society.

The scope involves an interpretation of the sector by theme, the purpose being to suggest priority lines of study in three major areas in construction: water, energy and materials, in an approach to the constructed environment that focuses on buildings and systems. Individually, each of the subjects is very complex and in dealing with them we tried to focus on priority aspects, whose actions can lead to significant results in the short-term. In doing so, we were careful not to treat them in too simplistic a way. Other themes from the construction sector that were not dealt with should be the target of a separate study.

Among the themes and major areas of relevant impact that can be the studied in the future, are the diagnosis of and recommendations for the construction site, for project practices and for urban policies.

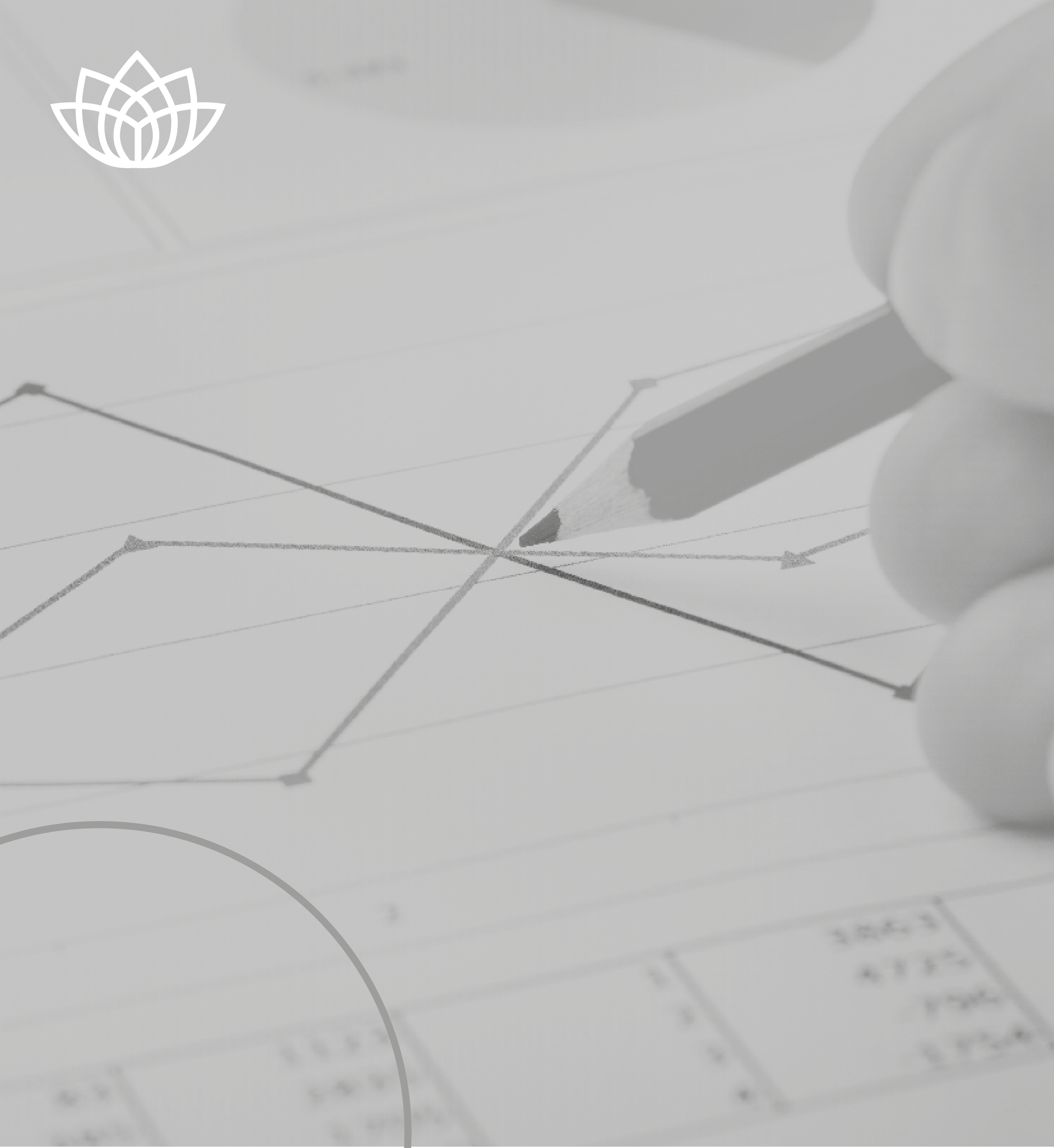
Dealing specifically with the last topic mentioned, there is growing recognition by society of the importance of urban issues, above all those relating to mobility, social costs, security, housing shortage and water and energy consumption. Measuring the value of the public improvements that are added to public and private property is a structural item on the agenda of contemporary society.

There is a clear opportunity for the strategic repositioning of the government, which can be largely responsible for offering new public policies that are capable of encouraging and educating society through the introduction of new urban practices, the aim being to construct an innovative culture that considers consumption, waste production and manipulation, construction practices and the behavior of society vis-à-vis its constructed environment.

It is clear that this interpretation needs to continue in order to expand the scope and to deal with matters that are merely touched upon in this work.

At this moment in time this version proposes priority lines for Water, Energy and Materials, the objective being to contribute to the future of construction and improve its practices and processes.

Enjoy your read.



CONSULTATION OF SECTOR PROFESSIONALS

1. **Reason**

According to a projection published by the *IBGE* in 2013, until 2050 the Brazilian population will be growing at an ever-reducing pace and will begin to decline as from the 2040s. The profile of the population will also be altered. In 1990 the average age of Brazilians was 25.6 years and their life expectancy was 66.3; only 36.4 % of the population was 30 and over. In 2030, it is estimated that the average age of Brazilians will increase to 36 and 60% of the population will be 30 and over. There will be approximately 93.1 million households (Sustainable Brazil).

The impact of this alteration in the demographic profile on the economic question is enormous and challenging and must be considered. These data indicate that:

1. There will be an increase in the elderly population and consequently a smaller increase in the active population (*EPE*, 2014c).
2. To compensate for the slowing in the increase of the active population the recommendation is to invest in improving productivity (*ABRAMAT*).
3. As there will be more adults, there will be more possibility of forming families and greater demand for dwellings, resulting in an increase in the number of households (*EPE*, 2014c).
4. The study estimates that by 2030, 91.1% of the population will be living in cities (ERNST & YOUNG; FGV, 2008).
5. There will be a decrease in the number of inhabitants per household due to the drop in fertility and increase in the income of the population, which allows more people to live alone. It is estimated that by 2050 this ratio will be 2.3 inhabitants per household (*EPE*, 2014c).

This scenario allows us to predict a greater demand for constructions and greater consumption of inputs associated with the use and operation of these developments. Looking merely at the construction of dwellings, the estimated impact will be large, from which we can predict that the impact on commercial buildings, services and other urban constructions will also be considerable.

It was based on this scenario that we carried out a survey with sector professionals regarding the promotion of sustainable construction.

2. **Survey Execution**

The focus of the survey is the constructed environment, in other words, actions linked to buildings and construction systems centered on demand management. Water, energy and materials are consumed at different times in the constructed environment. Water and energy inputs in this study are mainly dealt within the project and operation phases and material is dealt with from its selection, in the project and the construction phases, to its final disposal.

The objective of this research was to carry out a survey with agents in the construction sector to serve as the basis for a plan of actions that promotes sustainable construction. We looked for information about energy efficiency, the rational use and management of water and the selection and disposal of materials in the constructed environment to understand the activities of the sector and its needs, and to identify bottlenecks in order to propose actions.

To understand agent activities two surveys were undertaken with sector professionals: one qualitative and one quantitative. In the quantitative survey 381 professionals expressed their opinions about the subject through both open and closed questions. They also had the opportunity to comment on all of the questions and to reply to an open text question at the end. The qualitative survey consisted in conversations with three professionals, one from the energy sector, one from the materials sector and one from the water sector. In these conversations the professionals were able to express their points of view, share their knowledge and make suggestions about the subject; their comments were incorporated into the technical reports in each area.

3. **Quantitative survey: consulting sector professionals**

The survey was carried out through an electronic questionnaire on the Survey Monkey platform. It was organized in five blocks: (1) the profile of the interviewee; (2) eight questions about materials; (3) eight questions about water; (4) eight questions about energy; and (5) one open question.

The questionnaire was prepared and applied via the Internet and designed so as not to take more than 10 minutes to answer. The three major themes – Water, Energy and Materials – were organized into three sub-themes: the first questions in each group were prepared to find out about and understand how the respondent approached issues relating to the use of the resource; the second sub-theme allowed the respondent to position themselves with regard to the barriers in this approach; and the third sub-theme was for the respondent to choose recommendations from a suggested list. At the end of the three groups a dissertation-type question was included suggesting priority actions to be implemented by the public sector at any level.

The survey was available for nine days, from September 23 until October 1, 2014, and was sent to those on the email lists of the *CBCS* and its partner entities, resulting in a total of 381 respondents.

The survey seeked information in the following phases of the life cycle of the building: (1) manufacture, materials and components; (2) the construction site; (3) building operation and management; (4) local waste generation; and (5) waste disposal.

The questions were mostly multiple choice and allowed for more than one option to be chosen, which leads to results greater than 100% when analyzed because the same person may select two or more items in their reply.

The following analysis is based on the data collected. It is available in full in the Appendix.

4. **Respondent profiles**

People from different regions in Brazil took part in the survey. Of the 381 participating respondents, 55% are from the southeast region, 19% from the south, 10% from the northeast, 9% from the mid-west and 7% from the north.

Among the participants, 28.5% work in the project area, 26.6% work in research and academia and 25.9% are consultants. The respondents work mainly with commercial developments (37.4%), with average standard residential developments (29.7%), with high-end residential developments (25.6%) and with social housing (21.1%).

Of the total number of respondents, 32.9% are most familiar with the project stage.

The above data show a profile of survey respondents, who are predominantly project architects involved with commercial developments and different types of housing development concentrated in the south and southeast of Brazil.

5. **Analysis of the survey data**

Analyzing the survey data we notice that there are demands and needs in common in the three areas, which leads us to conclude that here we are dealing with sector needs. These needs are described below and their specificities will be dealt with in the technical reports of each area.

The three areas point to:

- a lack of knowledge, a need for campaigns for enlightening the population and demand for a greater degree of technical training for those involved;
- the need to create specific tools;
- the need to create incentives and lines of credit;
- a demand for specific legislation and regulations.

The results' analysis is presented below and details the relevant points indicated in these four needs.

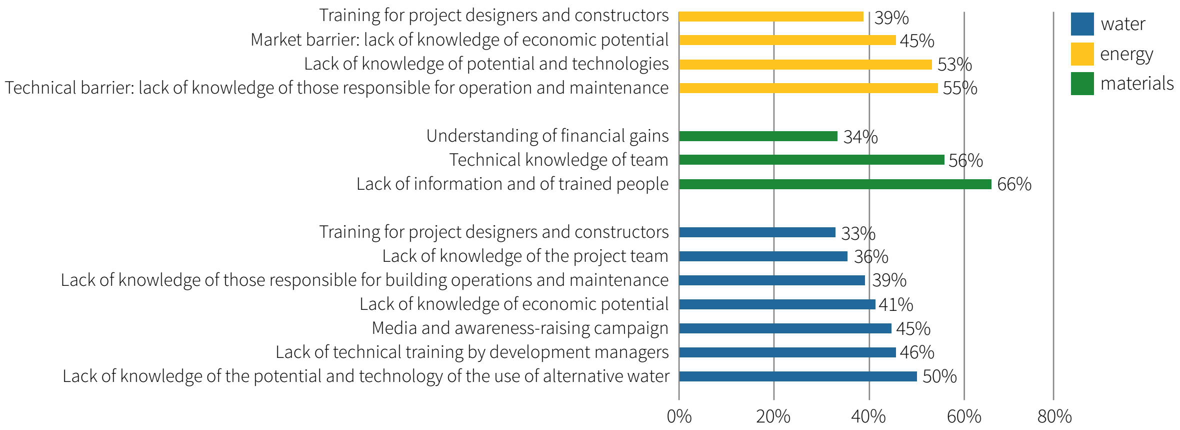
Need 1: Education, training and disclosure

Figure 1 shows the replies associated with education, training and disclosure, grouped by resource. Analyzing the graph, we note that in the energy area, education is seen as a technical barrier because of the lack of knowledge of those responsible for the operation and for maintenance (55%), followed by a lack of knowledge of the potential and the technologies available (53%). In the materials' area, the lack of information and of trained professionals is most mentioned (66%). In the water area the most mentioned fact is the lack of knowledge of the potential and the technologies available and the use of alternative water (50%).

In the comments of the respondents, there is a clear demand for an extensive review of engineering and architecture courses. Also mentioned was the need to act through campaigns for high school students and specific sectors, like condominiums, hospitals and hotels.

It is clear that in all the areas at least 50% of those interviewed think that there is some lack of information. We conclude that the spreading of information cannot be ignored in any sustainability initiative.

FIGURE 1 – EDUCATION, TRAINING AND DISCLOSURE



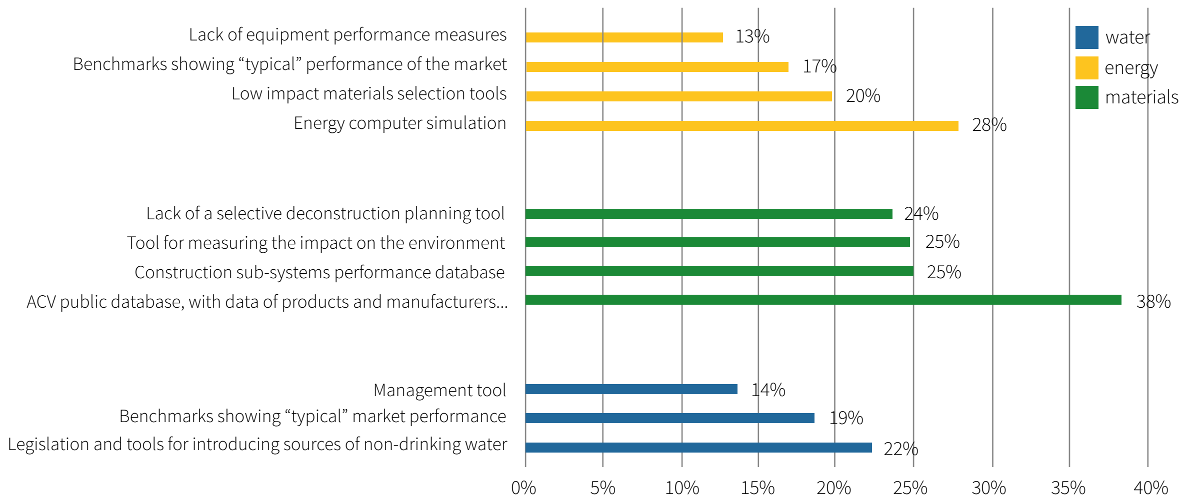
Using the free text question the respondents suggest campaigns that publicize exemplary cases involving sustainable solutions. They point to the important role of government – federal, state and municipal – and how the buildings they build and occupy should set an example. They cite educational and publicity campaigns in the media. They also recommend publicizing technical entry data, like rainfall figures.

Need 2: Demand for tools

The data regarding the request for specific tools were grouped in Figure 2. In this graph we can see that the respondents in the energy area would like to have access to more energy computer simulation tools (28%). In the materials area, the respondents indicate the need to create a public Life Cycle Analysis (*LCA*) database (38%), with information about Brazilian products and manufacturers. Respondents believe that the water area is lacking in tools for helping introduce alternative water sources (22%).

In the free texts, respondents suggest that a freely-accessible public database should be set up that has environmental parameters, like service life, thermal comfort, energy consumption, CO2 emissions and other aspects. They ask for the creation of a Brazilian public database that has an interface with management tools, like the Building Information Model (BIM). In order to use these tools successfully they also ask for definition of the measures and for the setting up of benchmarks for virtual performance assessment that can be publicly accessed. There is also a demand for tools that simulate the financial profitability of projects.

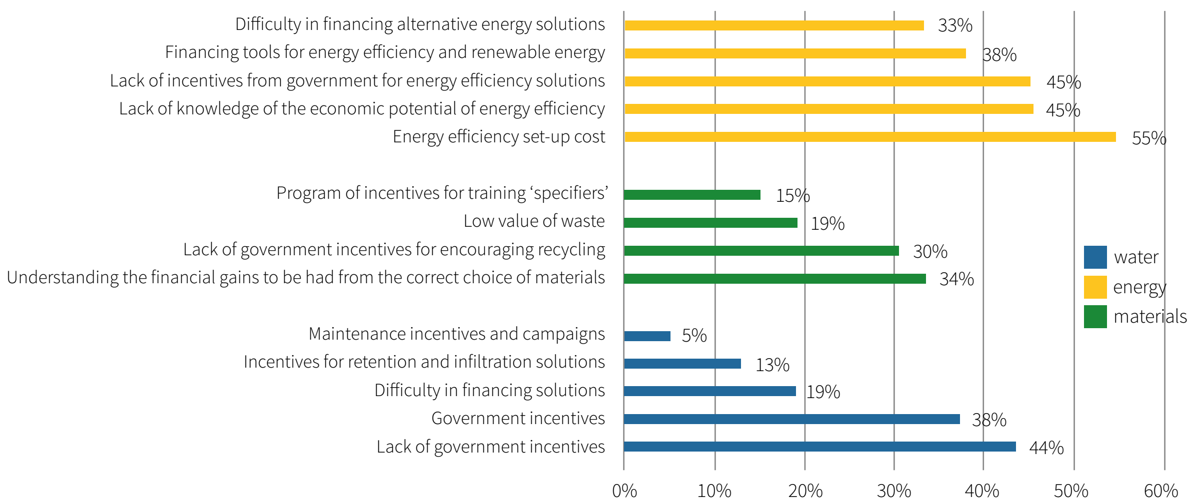
FIGURE 2 – DEMAND FOR TOOLS



Need 3: Demand for incentives and financing

Figure 3 groups the information about the demand for incentives and financing by area. In the energy area, respondents would like to see incentives and financing associated with the cost of introducing energy efficiency solutions (55%). In the materials area, the demand is for incentives and financing for the correct choice of materials (34%) and incentives for recycling (30%). In issues associated with water, there is a demand for different lines of incentive from government (44%).

FIGURE 3 – DEMAND FOR INCENTIVES AND FINANCING



We understand that respondents believe that if there were more incentives and lines of credit there would be more solutions in building developments.

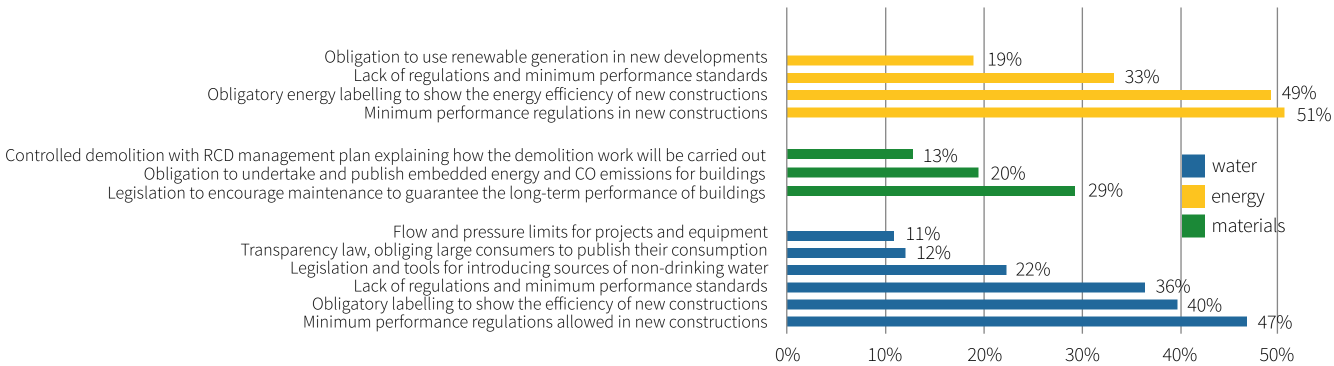
They mention the need to include technology in buildings; incentives for investment in research, for professional training and for the refurbishment/retrofit of existing buildings, and tax incentives, credit lines and incentives for startups in the area.

Need 4: Legislation, regulation and certification

Figure 4 shows the replies that deal with legislation, regulation and certification. The survey indicated that in the energy area 51% of the respondents believe that a minimum performance level regulation for new buildings needs to be created. Some 49% of the respondents believe that the energy label should be compulsory. With regard to materials, 29% of the respondents would like to see legislation to encourage maintenance and to guarantee the long-term performance of buildings. With regard to actions linked to water, 47% of the respondents would like to see a minimum permitted performance level regulation for new buildings.

In the comments, it is evident that there is a demand for regulations for establishing minimum technical performance requirements for all types of construction, a demand for adapting Master Plans and Building Codes to fit the concepts of sustainability and the need to bring together academia (technicians) and the legislators. Respondents indicate the need for integrated policies, in other words, the need for integrating the different federal, state and municipal spheres and the integration of different areas: water x energy, materials x energy. The respondents would like to see minimum performance levels made compulsory, like the compulsory nature of the *Procel* Program.

FIGURE 4 – LEGISLATION, REGULATION AND CERTIFICATION



It is worth mentioning that in the qualitative interviews a model of the stages required for approving legislation and regulations was suggested. The first stage for the creation of a law would be to propose a methodology that has defined measures and tools, thus offering the instrument for its application. The second stage would be validation of the proposal by the sector, through a pilot project or a voluntary adherence program. The third stage would be a partnership with the sector, which would allow for the creation of sector agreements so the legislation is successful. Finally, the fourth stage would make the proposal compulsory in the form of law.

Highlights of the free suggestions

In the comments of the respondents taken from the quantitative research, it was suggested that the payment of development contracts should be linked to performance indicators and that they should be established by public tender. It was also suggested that all contracts for public projects and construction work that are put out to tender should require a minimum number of sustainable measures, both in the construction phase as well as after the construction has been completed.

Various times in the comments it was pointed out that the conventional public tender format currently used makes the acceptance of industrialized and innovative products difficult, since it only takes into consideration traditional technologies and gives preference to the lowest cost quoted for doing the work. It does not take into consideration costs throughout the life cycle.

A challenge was thrown down in the free text and qualitative interviews: how to deal with the self-construction segment. It is a well-known fact that this segment consumes a lot of materials and that its labor force is poorly qualified. Ways need to be found of training this public and providing them with information.

The need was also raised to regulate and more strictly supervise the percentage of permeable areas of projects, thus guaranteeing that water filters down into the water tables.

6. **Final comments on the survey**

The intention of this study was not to prepare a balanced sample of the population of agents in the sustainable construction sector. Such a study would need to undertake a census of professionals in a sector that is very dynamic and would require very much more sophisticated techniques for collecting and processing data.

However, within the scope of collecting information for promoting sustainable construction, a voluntary questionnaire proved to be a very effective technique. The quantitative survey was considered to be a success and there was a very much greater degree of participation than was expected. This high participation rate shows the sector's wish to have a channel to express its concerns and its desire to see policies that have an impact on spreading sustainability practices in the sector.

PART I

WATER

1. Introduction

Water vulnerability in cities

In 1992 the United Nations Organization (UN) issued a document entitled "Universal Declaration of Water Rights" (IFRAH, 1992), which declares among other things that: "Water should not be wasted, nor polluted, nor poisoned. Generally speaking it should be used consciously and with discernment so that it never runs out or deteriorates in the quality of the reserves currently available". People have now developed an awareness that water is not an inexhaustible resource.

Considering the 10 biggest economies in the world according to the World Bank (THE WORLD BANK, 2013), Brazil has the largest water availability *per capita*, 4.5 times greater than in the United States and 21.5 times that of China. Table 1 shows renewable fresh water availability *per capita* in the countries with the largest Gross Domestic Products in 2013, according to the UN's Water Committee (UN-WATER).

TABLE 1 – RENEWABLE FRESHWATER AVAILABILITY IN THE COUNTRIES WITH THE BIGGEST GDPs IN 2013

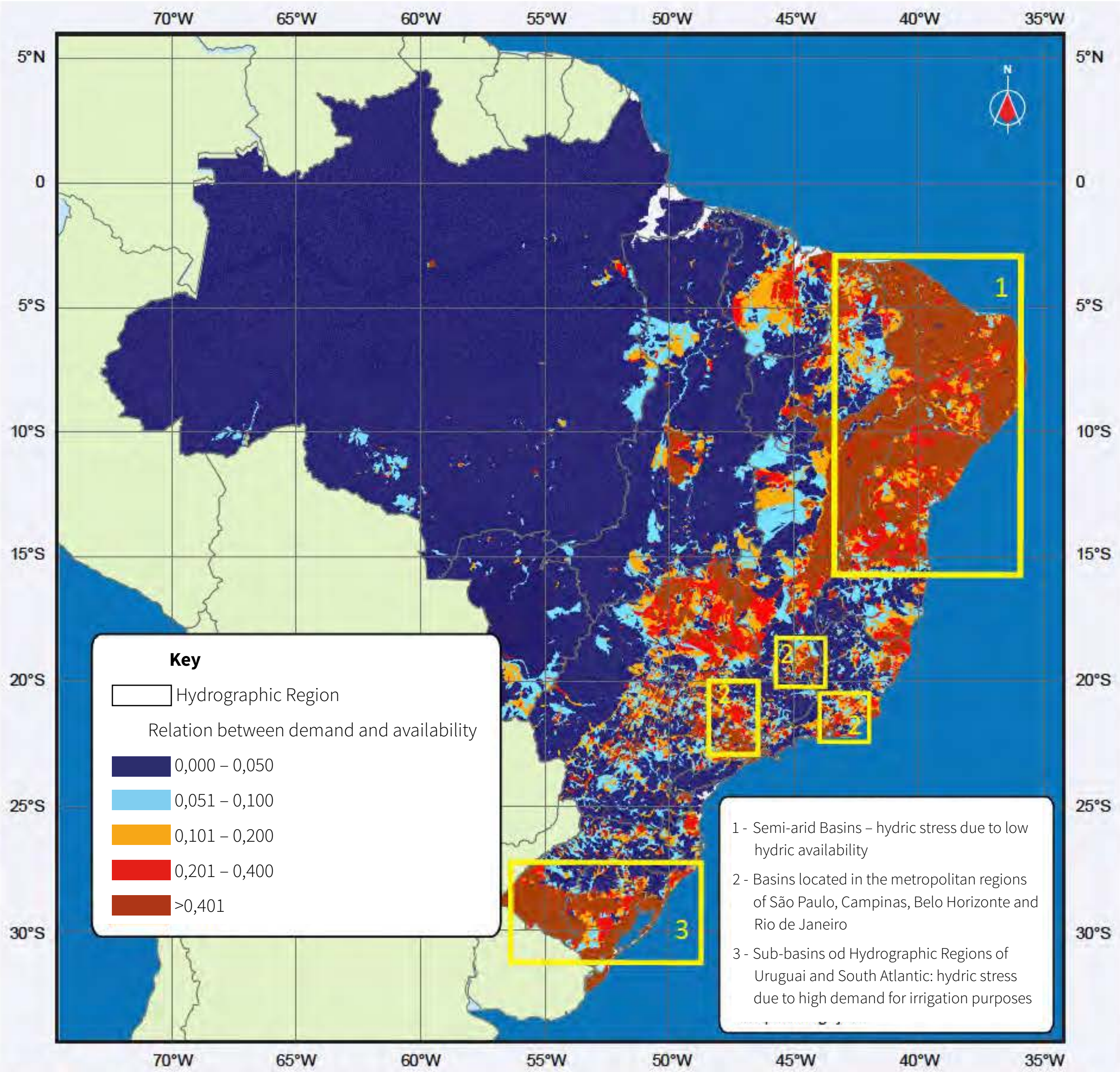
Country	Availability of renewable freshwater *per capita* (m^3/inhab/year)
Brazil	43,528
Russia	31,487
United States	9,666
Japan	3,379
France	3,300
Italy	3,142
United Kingdom	2,332
China	2,017
Germany	1,860
India	1,545

SOURCE: UN-WATER

This apparently comfortable water supply situation does not reflect the real distribution of the resource in Brazil. According to the National Water Agency (*ANA*, 2013), of the Ministry of the Environment (*MMA*), the Amazon Hydrographic Region has 80.8% of the available surface water and 61.9% of the potential exploitable reserve of underground water.

ANA (2013) compared water availability and demand for water. Considering the water removal rate, the Water Exploitation Index (WEI)1, the situation of the main Brazilian water basins was determined and mapped out in Figure 5.

FIGURE 5 – WATER AVAILABILITY vs. WATER DEMAND



SOURCE: ANA (2013)

Available Brazilian water comes both from surface water as well as underground water. According to *ANA* (2013), a comparison of the stored volume of water *per capita* makes it possible to identify the degree of water vulnerability for serving the uses for which the

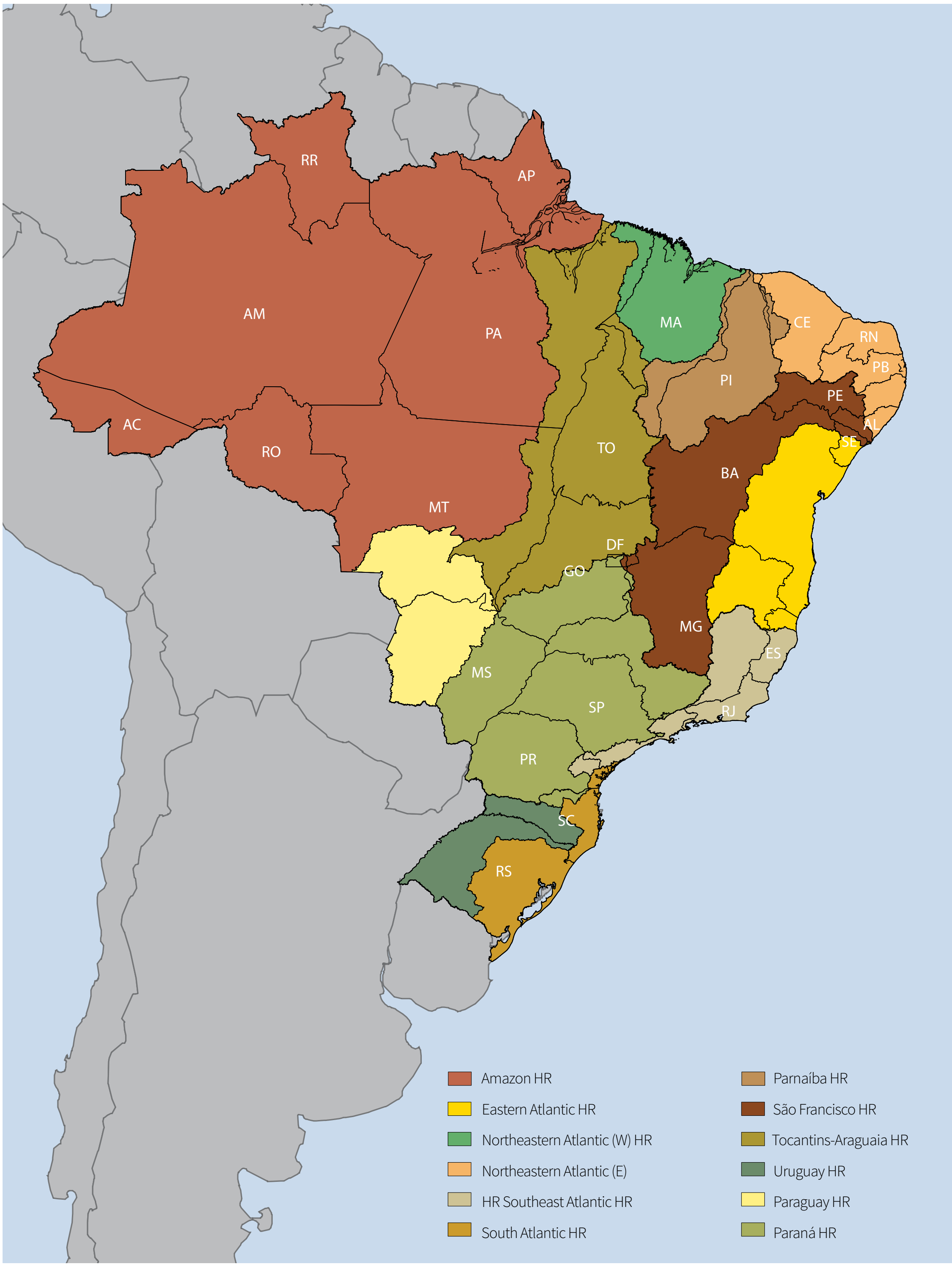
[1] The water exploitation index (WEI) in a country is defined as the average annual volume of freshwater ccollected, divided by the average long-term freshwater resources. It indicates how total water collection puts pressure on water resources. It identifies those countries that extract a lot relative to their resources and, therefore, are susceptible to suffer water shortage problems. Average long-term freshwater water resources are derived from average long-term precipitation less average long-term evapotranspiration plus average long-term entry from neighboring countries" (LALLANA; MARCUELLO).

resource is needed. According to *ANA* (2013), "Brazil has 3607m³ per inhabitant of maximum volume stored in artificial reservoirs".

Also according to *ANA* (2013), "use of water resources is understood to be any human activity that in any way alters the natural conditions of surface or underground water". So, this includes both uses that return all the water used to the water course (energy generation, navigation, fishing, tourism), called non-consumptive use, as well as uses in which part of the water does not return to the water course (urban use, industrial use, irrigation, watering animals), which is called consumptive use.

Figure 6 shows the map of Brazil's hydrographic regions and Table 2 shows surface and underground water availability, storage capacity and predominant type of use by hydrographic region in 2010.

FIGURE 6 – BRAZILIAN HYDROGRAPHIC REGIONS



SOURCE: ANA; MMA (2007)

TABLE 2 – SURFACE AND UNDERGROUND WATER AVAILABILITY, STORAGE CAPACITY AND PREDOMINANT TYPE OF USE BY HYDROGRAPHIC REGION IN 2010

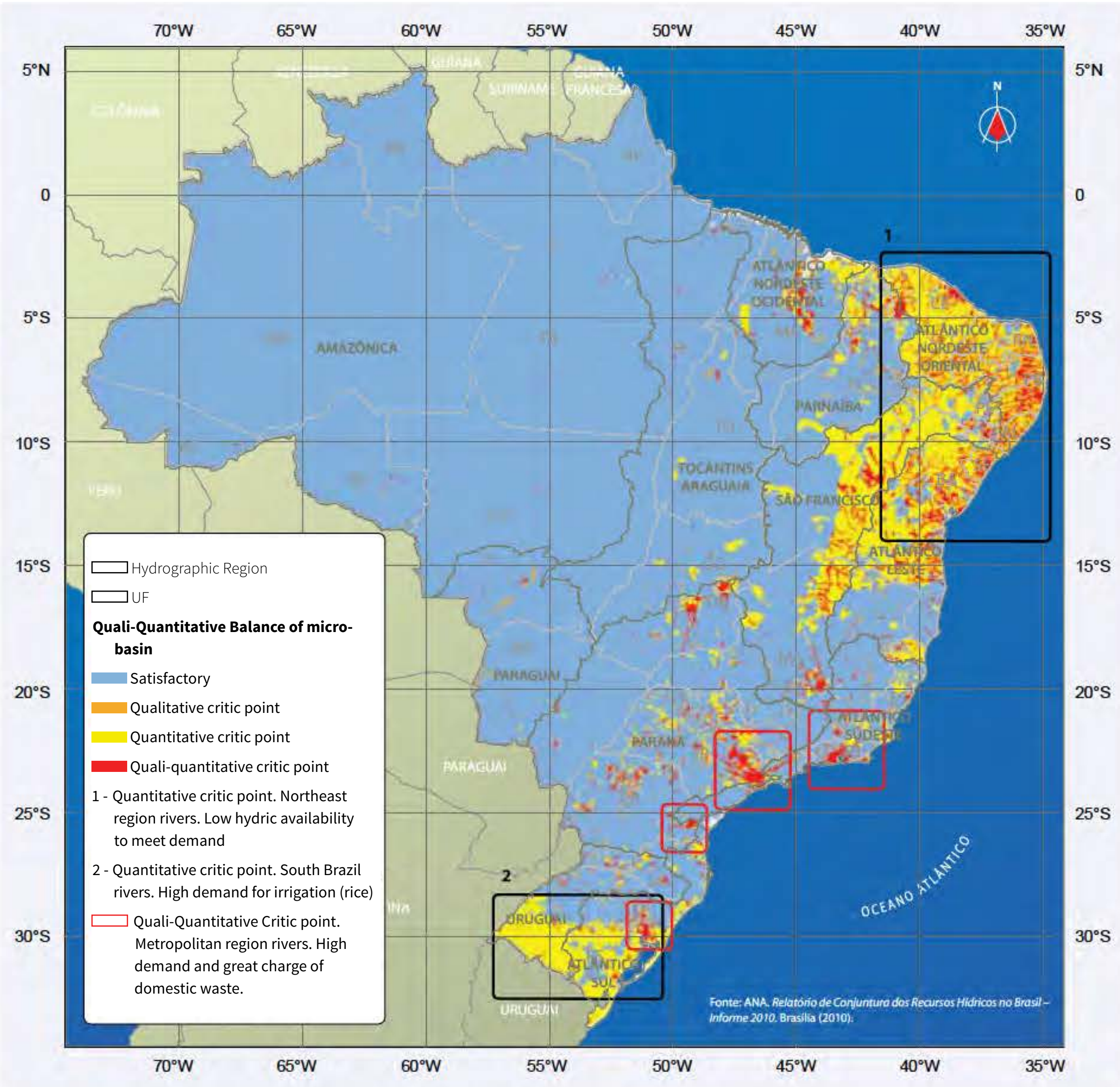
Hydro-graphic region	Water availability		Storage capacity *per capita* (m³/ inhabitant)	Predominant use
	Surface (m³/s)	Potential exploitable reserve* (m³/s)		
AMAZON	73.748	7.078	2.181	Low removal flow
PARANÁ	5.956	1437	4.047	Predominantly used for irrigation (40% to 50% of total demand)
TOCANTINS--ARAGUAIA	5.447	604	13.508	Predominantly used for irrigation (more than 60% of total demand)
SÃO FRANCISCO	1.886	355	5.183	Predominantly used for irrigation (more than 60% of total demand)
SOTHEAST ATLANTIC	1.145	146	372	Predominantly urban use
PARAGUAY	782	617	3.449	Low removal flow
SOUTH ATLANTIC	647	212	11.304	Predominantly used for irrigation (more than 60% of total demand)
URUGUAY	565	400	3.388	Predominantly used for irrigation (more than 60% of total demand)
PARNAÍBA	379	227	1.795	Low removal flow
NORTHEAST ATLANTIC (W)	320	183	–	Low removal flow
EASTERN ATLANTIC	305	85	945	Predominantly used for irrigation (40% to 50% of total demand)
NORTHEAST ATLANTIC (E)	91	86	1.080	Predominantly used for irrigation (more than 60% of total demand)
Total	91.271	11.430	3.607	

*Part of the annual rainfall that infiltrates into and actually reaches free aquifers and that can be sustainably exploited.

SOURCE: ANA (2013)

Serving the needs of water demand requires an assessment of the quality of the input available. Considering the quality indicator, like the assimilation capacity of water bodies, *ANA* (2013) analyzed the critical quantity (water availability) and quality (effluents) conditions of Brazilian drainage basins, shown in Figure 7.

FIGURE 7 – CONDITION OF BRAZILIAN DRAINAGE BASINS ACCORDING TO THEIR QUALITATIVE AND QUANTITATIVE CRITICALITY



SOURCE: ANA (2013)

It is obvious that the drainage basins where the metropolitan regions are located are the most critical both qualitatively and quantitatively as a result of the great demand there is for water, added to the amount of organic domestic load discharged into water bodies.

The Paulista Macrometropolis, one of the areas marked in Figure 3 as being qualitatively and quantitatively critical, covers approximately 52,000 sq. km. and is home to more than

30.8 million people (*DAEE*, 2013)[2]. This region includes, either totally or partially, eight Water Resource Management Unit (*UGRHI*) areas. Figure 8 shows the hydrography of the Paulista Macrometropolis.

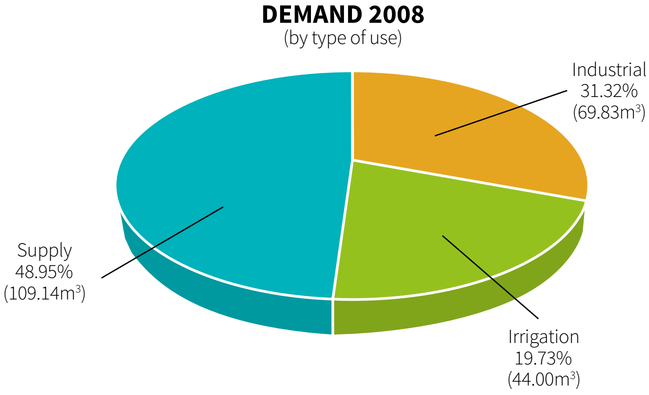
FIGURE 8 – MAIN HYDROGRAPHY OF THE PAULISTA MACROMETROPOLIS

SOURCE: *DAEE* (2013)

According to the Master Plan for the Use of Water Resources for the Paulista Macrometropolis, published in October 2013 (*DAEE*, 2013), total water demand is 222.96 m^3/sec., distributed across its different uses, of which approximately 50% is for supply (as can be seen in Figure 9, which also shows the region's other uses for water).

[2] Department of Sanitation and Water Resources (2013).

FIGURE 9 – WATER CONSUMPTION BY TYPE OF USE IN 2008



SOURCE: DAEE (2013)

The Master Plan gives a projection of the region's population, with a growth expectation of 20% until 2035, compared with that recorded in 2008. Table 3 shows the result of the population projections for 2018, 2025 and 2035.

TABLE 3 – POPULATION PROJECTIONS BY WATER RESOURCE MANAGEMENT UNIT

UGRHI	2008	2018	2025	2035
Paraíba do Sul	1.948.520	2.176.529	2.298.477	2.405.612
Litoral Norte	242.331	282.644	306.005	330.282
Piracicaba/ Capivari/Jundiaí	5.022.874	5.673.617	5.984.388	6.217.851
Alto Tietê	19.533.758	21.310.657	22.206.211	22.938.472
Baixada Santista	1.664.929	1.857.493	1.960.432	2.048.752
Mogi Guaçu	535.798	594.596	621.814	641.581
Tietê/Sorocaba	1.828.429	2.109.243	2.253.517	2.375.576
Ribeira do Iguape e Litoral Sul	45.617	53.308	58.271	63.557
Total	30.822.256	34.058.087	35.689.115	37.021.683

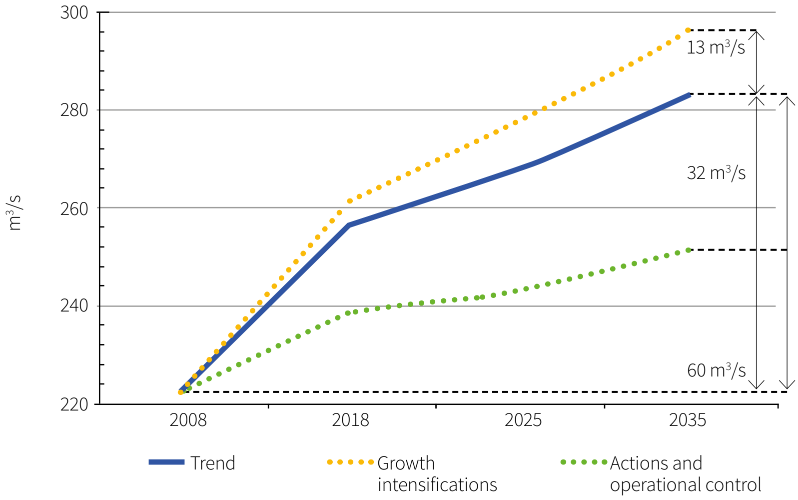
SOURCE: DAEE (2013)

This increase in population will inevitably lead to a significant increase in demand for water which, following the tendency curve, will require a further 60m³/sec.

Based on this table, the graph in Figure 10 shows the demand projection curve considering various scenarios: demand tendency, demand with Brazilian growth intensifying[3], and demand subject to management and operational control actions.

[3] As explained in the Master Plan, "in forecasting the Brazilian Growth Intensification scenario the growth considered was based on the GDP projection of the State of São Paulo and its expected increase as a function of the infrastructure projects being planned for the State and the more pronounced growth of the country. [...] the growth projection reflects the potential impacts that the infrastructure and energy development proposals, whch are under discussion in Brazil and the State of São Paulo, could have on the demand for water resources" (*DAEE*, 2013).

FIGURE 10 – PROJECTED TOTAL DEMAND CURVE IN THE SCENARIOS: TENDENCY; WITH ACTIONS FOR MANAGING AND OPERATIONALLY CONTROLLING DEMAND; AND WITH INTENSIFICATION IN BRAZILIAN GROWTH



SOURCE: DAEE (2013)

The Master Plan considers that it will be necessary to introduce demand management actions that will make it possible to reduce projected demand for 2035 by 32 m^3/sec. The planned actions are: (a) a reduction in the rate of loss in public networks; (b) demand management in buildings – programs for the rational use of water and behavioral changes; (c) technological changes and the management of water use in irrigation; and (d) cleaner production technology and regulations for charging for water use in industry.

In observing the scenario presented it is clear that managing water demand in buildings, especially in urban centers in regions that are vulnerable in terms of water supply, is a matter of emergency in Brazil, regardless of any lack of rain at certain times or in certain regions, as happened last summer in São Paulo. Guaranteeing that the amount of water available can be distributed to everybody is no longer a concern for the future.

“Water is certainly a factor that is important to the resilience of cities, both if it is present in excess, or if there is a lack of it”, according to Porto (2014).

2. National diagnosis

Urban sanitation and water management in cities

Every year the National Environmental Sanitation Department (*SNSA*), which is part of the Ministry of Cities, publishes its Diagnosis of the Water, Sewage and Waste Services, through the *SNIS*. The *SNIS* was conceived and developed by the Program for the Modernization of the Sanitation Sector (*PMSS*), which is linked to the National Environmental Sanitation Department of the Ministry of Cities. Its database contains information that is voluntarily supplied by state, regional and municipal water and sewage (and solid waste) collection and treatment service suppliers. The data have been collected, analyzed and published since 1995.

For the 2012 Diagnosis, which was published in 2014, data were collected from 5070 municipalities (91% of all the municipalities in Brazil), which have a population of more than 160 million people (98% of the urban population).

The *SNIS* (2014) gives the total service index for the supply of water through a network as being 82.7%, while the sewage collection index is 48.3%. These numbers are higher in urban regions, at 93.2% and 56.1%, respectively. Table 4 shows the levels of water and sewage service by geographic region.

TABLE 4 – WATER AND SEWAGE SERVICE LEVELS BY GEOGRAPHIC REGION AND BRAZILWIDE

Region	Network service index (%)				Sewage treatment index (%)	
	Water		Sewage		Sewage generated	Sewage collected
	Total	Urban	Total	Urban	Total	Total
North	55.2	68.6	9.2	11.9	14.4	85.1
Northeast	72.4	89.5	22.2	29.4	31	81.2
Mid-west	88	96.5	42.7	47.1	44.2	90
Southeast	91.8	97	75.4	80.3	42.7	63.6
South	87.2	97.2	36.6	42.7	36.2	79.7
Brazil	82.7	93.2	48.3	56.1	38.7	69.4

FONTE: BRAZIL (2014)

Also according to the *SNIS* (2014), average water consumption *per capita*[4] in Brazil was 167.5 L/per day. This average varies according to the state or region, as can be seen in Table 5 (which gives the average consumption *per capita* by region) and in the graph in Figure 11 (which shows the average consumption *per capita* by state).

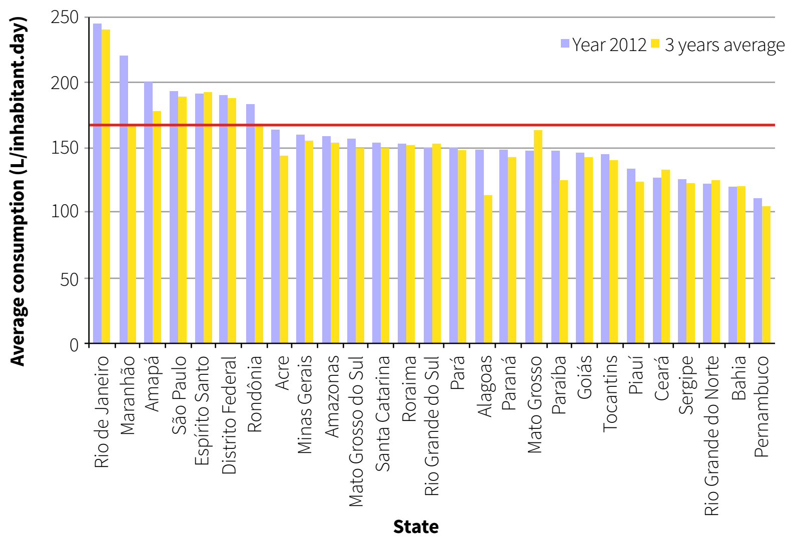
TABLE 5 – AVERAGE WATER CONSUMPTION *PER CAPITA* BY GEOGRAPHIC REGION

Region	Average consumption *per capita* (l/inhabitant.day)
North	155,8
Northeast	131,2
Mid-west	156,5
Southeast	194,8
South	149,3

SOURCE: BRAZIL (2014)

[4] "The average water consumption per capita is defined in the *SNIS*, as the volume of water consumed, excluding the volume of water exported, divided by the population served with water supply" (BRAZIL, 2014).

FIGURE 11 – AVERAGE CONSUMPTION *PER CAPITA* FOR THE AVERAGE OF 2010, 2011 AND 2012



SOURCE: BRAZIL (2014)

The graph in Figure 11 shows that in most of Brazil's states consumption has tended to grow (average consumption in 2012 was greater than the average for the years 2010, 2011 and 2012).

The data supplied by the National Sanitation Information System confirm that in the large urban centers both water and sewage service indices and *per capita* demand are increasing.

Water Demand Management (*GDA*) in cities includes controlling losses in the water supply networks, using alternative sources of water and managing water demand in buildings.

With regard to losses from the supply networks, according to the *SNIS* (2014), Brazil has high indices of water loss during distribution (IN049[5]). Table 6 shows IN049 by Brazilian geographic region.

TABLE 6 – LOSS INDEX IN DISTRIBUTION BY GEOGRAPHIC REGION AND BRAZILWIDE

Region	IN049 (%)
North	49,3
Northeast	44,6
Mid-west	32,4
Southeast	33,5
South	36,4
Brazil	**36,9**

SOURCE: BRAZIL (2014)

[5] The IN049 indicator compares the volume of water made available for distribution and the volume consumed, which shows the loss index.

Control of water loss from distribution networks is the object of the National Sanitation Plan (*PLANSAB*), of the National Environmental Sanitation Department, of the Ministry of Cities.

The second aspect of managing water demand in cities, the use of alternative water sources, considers the use of water not coming from the public drinking water supply system.

According to the Brazilian Council of Sustainable Construction (*CBCS*, 2009), the most widely-used alternative water sources in building systems are making use of rainwater, the use of treated effluent ("reuse water") and artesian wells. In such cases the building can be considered to be a "water producer" and the managers of the water system become responsible for the quality of this water and for the way in which it is used.

Reuse water is defined by *CBCS* (MARQUES; OLIVEIRA, 2013) as non-drinking water obtained by retaining residual water, which is defined as "effluent generated after the use of water in residential, commercial and industrial buildings". Reuse can be indirect, which is characterized as being when residual water is discharged into bodies of water (surface or underground water) and used again 'downstream', or direct, when there is planned and immediate use, after the effluent has received the treatment that is appropriate for the use to which it will be put.

The International Reference Center in Water Reuse (*CIRRA*)[6] describes different types of reuse, among them urban reuse.

Reuse potential is very broad and diversified. The use of treated effluent requires a control of water quality and must take into account the costs of introducing such a system and of operating it. Generally speaking, this system is only feasible for non-drinking uses and must be carefully planned and operated (HESPANHOL, 2008).

According to Hespanhol (2010), "some sanitation companies are currently preparing to supply so-called 'reuse water' or 'utility water' for non-drinking water uses in urban areas". An example of this is the Aquapolo Project that produces reuse water for the ABC Paulista petrochemical complex. Aquapolo is an Industrial Water Producing Station (*EPAI*), with reuse water flow capacity of 1m^3/sec. (AQUAPOLO PROJECT, 2010).

The third aspect of managing water demand in cities, water demand management in buildings, is the main theme of this document.

Managing water demand in buildings

According to Silva (1999), water management can be approached on three levels: the macro-level, which is associated with actions on the scale of large environmental systems and water basins; the meso-level, with actions in sanitation systems, involving sanitation and sanitary sewage services; and the micro-level, related to actions that concentrate on buildings and their water and sanitation systems.

For many years, efforts were concentrated on managing water supply (macro and meso levels), which involved collecting water from increasingly more distant locations and extending supply networks. According to Silva, Tamaki and Gonçalves (2006), "with most of the

[6] Available at: <http://www.usp.br/cirra>.

possibilities of this model exhausted and with it becoming increasingly more expensive, also bearing in mind the question of sewage management, a change in the paradigm occurred: from exclusively supply management to managing demand too" (micro-level), [which is] "more coherent with the precepts of sustainable development".

According to Silva (2004), water demand management can be understood as being the permanent monitoring of the volume of water consumed, and the organization and assessment of the data and information that determine the control parameters (monthly consumption, *per capita* consumption, flow profiles, etc.) that feed back into the system and allow for action planning for maintaining the consumption indicators at adequate levels, whether by eliminating physical losses, using new technology or by reviewing a process that uses water.

A water demand management system in buildings comprises a set of preventive (routine) and corrective (when necessary) actions that, under the responsibility of the manager, guarantee that water consumption indicators are maintained.

The sectorization of water consumption is an important demand management action and this is done in buildings by installing hydrometers that are located at strategic points in the water system and that make it feasible to meter partial volumes consumed. Knowledge of these partial volumes enables: (a) the establishment of consumption monitoring procedures; (b) any increases in consumption to be discovered and located more easily; (c) the planning of preventive and/or corrective actions in the water system for maintaining consumption levels; (d) specific consumption in a particular sector to be tariffed (a school canteen, for example).

There is individual water metering when sectorization of consumption coincides with "savings". In residential apartments or commercial suites, for example, individual metering ensures that users can be charged for the water actually consumed in their unit, plus their share of the water consumed in the common areas.

According to Silva, Tamaki and Gonçalves (2006), adopting these tools, despite the technical, administrative, economic and financial difficulties that might exist, particularly in existing buildings, is compensated for by their benefits, such as: "(a) obtaining more data in real time in a more reliable way; (b) the possibility of collecting information, such as daily consumption and minimum flow levels; (c) faster and more accurate detection of anomalies, among which leaks (explained, for example, by a high minimum nightly outflow); and (d) greater correspondence between consumption and the consumer system (the possibility of charging for water consumed by third parties, such as restaurants, etc.)".

Managing water demand in buildings must include, among other things, the establishment of procedures and responsibilities when water consumption indicators rise. According to Silva, Tamaki and Gonçalves (2006), efficient leak warning and correction systems, building system operation and maintenance procedures (including maintenance and/or substitution of sanitary equipment) and indication of the need for the overhaul of water networks are some examples of actions in a water demand management system that help maintain the consumption indicators.

Structured systems of water demand management guarantee that actions for reducing consumption will be long-lasting.

Rational use of water and water conservation

Rational use and water conservation concepts must be defined when formulating water demand management programs in buildings.

The rational use of water, or the efficient use of water, is understood as a set of actions that optimize the operation of the building system in such a way as to reduce the amount of water necessary for consumer activities, maintaining them at agreed service performance levels — a focus on water demand.

Water consumption is defined as a set of actions that, in addition to improving the operation of the building system in such a way as to reduce the amount of water consumed, promote the supply of water produced in the building itself that comes from sources that are alternative to the drinking water supplied by the public system — a focus on demand and the internal supply of water.

According to Hespanhol (1997) *apud* May (2008), the use of water from sources that are alternative to the drinking water that comes from utilitiies for serving less restrictive demand helps reduce the consumption of drinking water and allows better quality water to be used for more important and critical purposes.

Among the possibilities for the use of water from sources that are alternative to the drinking water coming from utilitiies are making use of rainwater, artesian wells and the reuse of graywater.

According to May (2004), "when making use of rainwater for non-drinking consumption some care is necessary relating to the installation and maintenance of the system" in order to prevent contamination of the drinking water. Samples of rainwater collected between November 2003 and March 2004 in University City of the University of São Paulo were analyzed physically, chemically and bacteriologically and provided evidence of the fact that the samples were not fit for drinking and included the presence of bacteria and fecal coliforms coming from the feces of animals found on the surfaces from which the water was collected (roofs). "When rainwater passes through the atmosphere it absorbs the particles that exist there." The impurity characteristics of rain are related to the region where it is collected, so use conditions must be analyzed in each case. Rainwater cannot be mixed with drinking water. It must be separated from the water reserve and distribution system (MAY, 2004).

Alternative solutions to the drinking water coming from utilitiies require the attention of government, especially in residential buildings, most of whose managers (condo administrators, building managers and janitors) are not technically trained. Certain types of building (industrial, shopping centers, commercial centers and even some large hospitals) are better able to use non-drinking water safely because they have qualified maintenance teams.

The use of non-drinking water in buildings requires regulations that establish procedures and responsibilities relating to quality control and surveillance and the operation and maintenance of water systems to minimize the risk of contaminating the population.

In the rational use of water, management focuses on reducing the amount of water, by monitoring the variation in consumption indicators and taking actions in relation to the building system so that these indicators are maintained at adequate levels – demand management, with a focus on the amount of water consumed.

In water conservation, in addition to being concerned with the amount of water consumed, the variation in the quality of the water coming from alternative sources must be monitored to prevent the possibility of contamination of the building's drinking water system – supply management, with a focus on the amount and quality of the water supplied.

The actions and recommendations of this document are directed mainly at programs for the rational or efficient use of water in buildings. The objective is to significantly and permanently reduce the indicators of the water consumed by the population of cities without, however, discarding specific situations in which some modalities of the use of water not coming from the public drinking water supply system are applicable.

Once actions that promote the rational use and conservation of water have been adopted, buildings can think about reducing demand and consequently increasing the temporal reach of the supply system.

Oliveira (1999) classified actions for increasing the efficient use of water in buildings into three aspects: social (education and awareness-raising campaigns); economic (financial incentives, like reducing tariffs, and subsidies for acquiring systems and components that save water, or through financial discouragement in order to inhibit waste, by increasing water charges as a function of consumption separated into bands); technological (use of systems and components that save water, leak detection and correction).

Institutional Programs

Successful efficient water use programs must be structured and require, as their basis, institutional programs that lead to the creation of an environment of interaction between public agents – government bodies, regulatory agencies, service concessionaire, etc. – and private agents – sector entities of producers and retailers of materials and components, construction companies, project architects, facilities managers, consumer bodies, universities and research institutions, etc. They must also be characterized by actions of a technological, economic and social nature.

Brazil has already moved in this direction with the structuring and introduction of successful programs that can be reviewed, up-dated and resumed.

In 1994, the studies that gave rise to the series entitled "Modernization of the Sanitation Sector" (*MPO/IPEA*, 1994 to 1998, 15 volumes) indicated the need for the coordination of policies and programs directed at conservation and the rational use of water to be incorporated at the federal level.

In 1997 the National Program for Combatting Water Waste (*PNCDA*) was instituted, in line with the structure presented by Silva, Cojeno and Gonçalves (1999), which was linked with the involvement of ministries, representative entities from the sanitation sector and entities that are traditionally involved in the decision process. The overall objective of the program was "to promote the rational use of the public water supply in Brazilian cities in order to benefit public health, environmental sanitation and service efficiency, leading to better productivity of the existing assets and the postponement of part of the investments for expanding the systems". Its specific objectives were "to define and implement a series of concurrent actions and technological, economic and institutional instruments for effectively saving the volumes of water required for consumption in urban areas", which would occur through the following directives: "(I) to promote the production of reliable technical information in order to understand the supply, demand and efficient use of urban water; (II) to support the planning of integrated actions for the conservation and rational use of water in municipal, metropolitan and regional supply systems, including components of demand management (residential and non-residential), of operational improvement in supply and of rational use of water in building systems; (III) to support basic sanitation services in the management of technical and operational registers, with a view to reducing the volumes of water not billed; (IV) to support the basic sanitation services in their operational improvements, aimed at reducing physical and non-physical losses, particularly with macro-metering, micro-metering and pressure control in the network and a reduction in operational consumption in the production and distribution of water; (V) to promote the technological development of low water consumption components and equipment for use in buildings, including technical standardization, practice codes and laboratory training; and (VI) to support quality management programs applied to the products and processes that involve the conservation and rational use of water in public and building systems".

Specialist studies were carried out within the scope of the *PNCDA* and documents were organized that would guide activities in the areas of "(a) planning, management and the institutional linking of actions for the conservation and rational use of water; (b) water conservation in public supply systems; and (c) conservation and the rational use of water in building systems. These documents would be prepared in a broad way, with a view to combatting water waste, by seeking efficiency in all phases of the use cycle, from collection to final consumption".

The Rational Water Use Program (*PURA*) (GONÇALVES & OLIVEIRA, 1997) was created in 1995 through a technical cooperation agreement between the Polytechnic School of the University of São Paulo (*EPUSP*), the Basic Sanitation Company of the State of São Paulo (*Sabesp*) and the Institute of Technological Research (*IPT*), with the support of sanitary ware (porcelain and metal) manufacturers. The objective of *PURA* was to avoid water waste by way of: "(1) technological actions for adapting equipment and combatting losses; (2) conscience and awareness-raising actions, with a change in user habits; and (3) management actions, with the permanent monitoring of water systems for enabling the rapid correction of any increases in consumption" (OLIVEIRA, 1999). While rationing policies, which are introduced in emergency situations, reduce consumption by imposing quotas, *PURA* was structured for the permanent use of the minimum amount of water necessary, but without compromising consumer activities. "This, therefore, is a long-lasting action, in contrast to rationing, which because it compromises consumption activities, implies it is temporary in character" (OLIVEIRA, 1999). One of the important characteristics of *PURA* is permanent demand management to guarantee that the smallest consumption possible is maintained over time. Implementation of optimization actions without adopting a management system allows consumption indicators to return to initial or greater levels.

There are six macro-programs in *PURA* that are developed simultaneously:

Macro-program 1 – Technology database, technical documentation and case studies;
Macro-program 2 – Rational Water Use Program's Institutional Laboratory (*LIPURA*);
Macro-program 3 – Technology Assessment and Adaptation Program (*PAAT*);
Macro-program 4 – Characterization of demand and the impact of water-saving actions in the housing sector;
Macro-program 5 – Documentation relating to legislation, regulations and sector quality programs;
Macro-program 6 – Specific programs for saving water in different types of building.

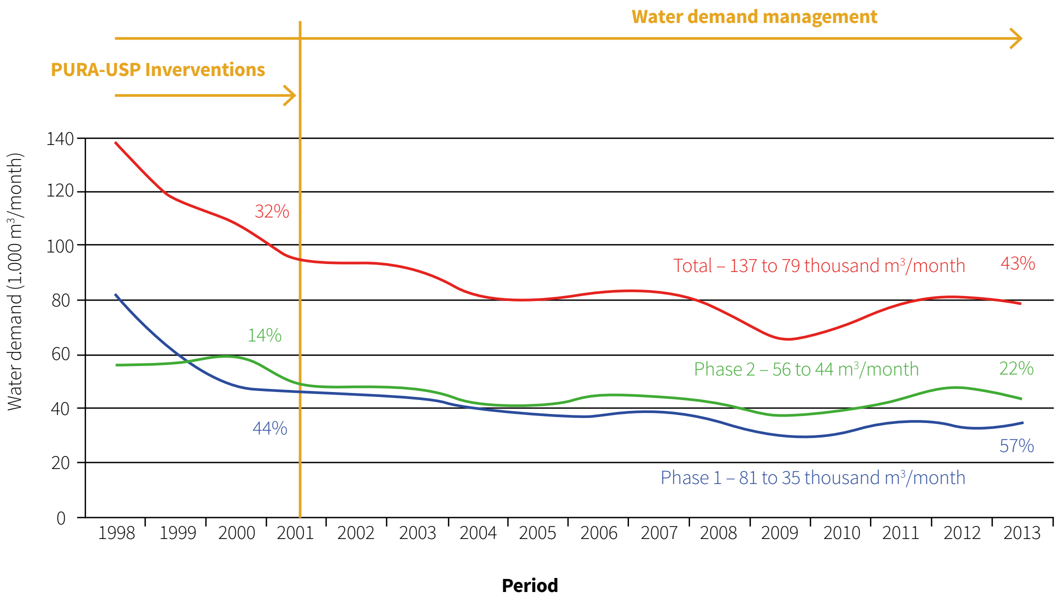
Case studies were undertaken in São Paulo in different types of building. This helped check the methodology that had been developed and began acquiring data for establishing consumption indicators that are compatible with consumer activities, considering the efficient use of water.

After determining and checking the introduction methodology, *Sabesp* signed various partnership agreements and the program was introduced on a larger scale: *PURA*-Schools, *PURA*-Hospitals, and *PURA*-Jails. Of all the programs that were introduced the highlight was *PURA-USP*, which because of the management system adopted has managed to maintain since 1998 the results of the actions that were introduced for reducing water loss and waste on USP's University City campus in São Paulo.

PURA-USP is an example of a permanent and effective program for managing water demand that has had significant results. It started in 1997 within the scope of *PURA's* Macroprogram 6, through an agreement signed between *USP* and *Sabesp*, the main objectives of which were (a) to reduce water consumption and keep it at reduced levels over time; (b) to maintain a structured water demand management system; and (c) to develop methodologies that are applicable to other locations. The program was introduced in five phases: (1) diagnosis (knowledge of the situation, checking the conditions of the points of consumption and of the water system, and data collection); (2) a reduction in physical losses (detection and elimination of leaks in the external systems and in reservoirs); (3) a reduction in consumption at points of use (detection and elimination of losses at points of use by regulating and substituting water commands, the search for and elimination of leaks in internal pipes, substitution of conventional equipment for water-saving equipment that is adapted to each type of use); (4) the characterization of habits and the rationalization of activities that consume water (adopting more efficient procedures for reducing waste without losing quality); (5) disclosure, awareness-raising campaigns and training. Stages 4 and 5 are permanent in nature.

A permanent monitoring and consumption management system was defined right at the outset. This was done by installing hydrometers and a remote metering system that enables a control center to monitor water consumption on the campus on a daily basis. This management system means that unexpected increases in consumption can be rapidly located, diagnosed and corrected, which reduces the possibility of water consumption in the university rising again. Since the start of *PURA-USP*, the population of the campus has grown by 13.3%, the constructed area by 16.3%, and water consumption has fallen from 137,881 m^3/month in 1998 to 78,821 m^3/month in 2013, which means a 43% reduction in monthly water consumption in the university.

FIGURE 12 – RESULTS OF *PURA-USP*



SOURCE: USP (2014)

To maintain the consumption reduction obtained with the investments that were made in rational water use programs, the experience that has been acquired from *PURA-USP*, in comparison with other programs that have been introduced, indicates that demand management is indispensable. For demand management to be effective the sectorization of water consumption is fundamental.

In large cities, which are becoming increasingly vertical, individual metering of water consumption, in addition to being an instrument for making it feasible to manage demand, also helps reduce consumption. According to Yamada, Prado and Ioshimoto (2001), "with individual metering users begin to acquire more awareness of the use of water, since they will be paying as a function of their own consumption. So water savings occur almost spontaneously, in other words, indirectly, without the application of any water conservation methodology". One of the other benefits of the individual metering of water is fairness in charging. Each consuming unit pays for the water it actually consumes, which helps cut down on waste. In a field study that Yamada, Prado and Ioshimoto (2001) carried out between March 1999 and May 2000 in a housing complex located in Guarulhos, SP, they found a reduction impact of around 17% in water consumption in buildings with individual metering compared with others that had collective metering. There have been various Brazilian experiments involving the individualization of water consumption. Possibly a pioneer in this field, *Compesa* in Pernambuco started experiments with individual consumption metering in buildings in 1994. In Goiânia, *Saneago* started the individual metering of water consumption in apartments in 2003. In 2005, in the Federal District, specific legislation made it compulsory to install hydrometers for individually metering water consumption in every housing unit, with a deadline of 5 years for existing buildings to adhere, with the option to sectorize consumption by apportionment in cases in which it was proved that it was technically unfeasible to meter individually. *Embasa* in Bahia adopted individual water metering in condominiums in 2006.

The challenges faced by individualized water consumption programs in existing residential buildings have to do with deciding on the correct specifications for the products and components of the metering system and installing it without damaging the building's existing water system. At the same time, buildings are being constructed without any provision for the infrastructure necessary for individually metering consumption, especially in those places where this approach is not compulsory. In these cases, to measure the water consumption of apartments individually, buildings are going to be burdened with refurbishment work that could have been avoided. There are also cases in which it will be impossible to introduce a metering system, because of the original hydraulic concept of the building.

Launched in 2008 by *Sabesp* in a partnership with the Polytechnic School of the University of São Paulo, *ProAcqua* is a program for installing individual metering in existing buildings. *ProAcqua* was structured in such a way as to guarantee the quality of the installations, without compromising the water system of the building and for the specification and installation of hydrometers that correctly read water consumption. The proposed program comprises four sub-programs: (1) the Innovative Products' Technical Assessment Program, in a partnership with associations of manufacturers and research bodies, with a focus on innovative technology, services and systems for guaranteeing the quality of the equipment; (2) a Training and Professional Recognition Program, in a partnership with associations of project architects and installers and with universities, with a focus on training, qualification and certification for guaranteeing the quality of service providers; (3) Quality Guarantee Programs, in a partnership with associations of manufacturers and universities, for monitoring the quality of the products and components manufactured and installed; and (4) the Environmental Education Program, in a partnership with universities and organizations, with a focus on educating professionals and condominium users for guaranteeing demand management and actions that ensure the efficient use of water.

Technology: quality, performance and innovation

Technological actions for reducing consumption and obtaining the efficient use of water involve the elimination of losses (visible and invisible leaks) and waste reduction. In both cases the contribution of the building industry is the basis for bringing to market materials, components and equipment that are efficient and provide a guarantee of quality.

Supported by funding agencies, the Brazilian Housing Quality and Productivity Program (*PBQP-H*) of the Ministry of Cities is important for guaranteeing the quality of construction (<http://pbqp-h.cidades.gov.br/>). It contains three main projects:

1. The Compliance Assessment System for Service Companies and Civil Construction Work (*SiAC*) regulates and monitors the compliance of service provision for those who design and construct;
2. The Qualification System for Material, Component and Construction System Companies (*SiMaC*) regulates and monitors the compliance of materials and components that are subject to standards; Sector Quality Programs for construction products are implemented within the framework of *SiMaC*;
3. The National Technical Evaluation System (*SiNAt*) regulates and monitors the technical assessment of technological innovation in components, subsystems and building construction systems.

The *PBQP-H*, allied with the purchasing power of the states, is an important instrument for encouraging quality. It combats non-compliance and helps guarantee that investments in public programs result in the expected return.

Technological actions must be planned, considering existing buildings and those yet to be built.

The water systems in existing buildings, especially the oldest ones, can be compromised in such a way that however much the users are made aware of the need to reduce consumption, they are unable to reach indicators that are compatible with the types of water use. The experience of other countries and some case studies in Brazil indicate that the modernization of water systems and the adaptation of equipment in existing buildings contribute significantly to reducing the demand necessary for those activities that consume water.

In new buildings the concepts of efficient water use need to be incorporated by the project architects, installers and construction companies in the conception and execution of modern architectural and water system projects that take into consideration the efficient use of water.

Regulations and standards

It is the regulation and standardization of products and services that guide a sector's production chain. An important step taken by the building sector was the publication in July 2013 of NBR 15575, Residential Buildings – Performance, which has become known as the "performance standard" and represents a framework for the technological modernization of Brazilian construction and an improvement in the quality of dwellings.

Various standards and regulations guide the life cycle of a building in the conception, design, execution and operation stages. With specific regard to building water systems, the requirements that are served by those responsible for making materials and components, project architects and installers determine the way the building will 'behave' during the whole of its service life.

There is a host of municipal state and federal laws on various aspects of technological themes that involve water conservation, such as individual water metering, making use of rainwater, solar heating and water reuse. But such laws, which are prepared without the necessary technical basis and without the inclusion of public and private agents, do not guarantee the effectiveness of the legal framework and may put at risk the health of the population.

Finally, laws, regulations and standards do not achieve the intended results without monitoring, whether by government, or by organizations of society itself.

Education, awareness-raising and training

Education and raising the awareness of the population are instruments for transforming water use habits, and not just at emergency moments of drought. New habits need to be acquired on a permanent basis.

Awareness-raising campaigns for users must form part of structured programs for efficient water use.

For example, environmental education in schools encounters citizens at an appropriate age for raising their awareness and multiplying the knowledge acquired. Understanding is incorporated by the children and they take it back to their families.

Brazil has some successful experiments in this area, throughnot-for-profit organizations that have established awareness-raising programs directed at efficient water user.

An example of this is the NGO, Water and City, which was founded on March 22, 2000 (World Water Day). Its objective is "to raise awareness and mobilize society for the rational use of the water supply and the conservation of urban rivers". Its mission is to "support and develop actions for the defense and maintenance of the quality of life of human beings, water resources and the environment through awareness-raising and technology programs"[7].

Water and City operates mainly on the basis of two programs:

Water in the School: starting from the principle that schools, like all public and private organizations, must commit to managing water, the objective of Water in the School is (a) to educate children about the rational use of water; (b) to train teachers who are sympathetic to the urban environmental cause so they become multiplying agents in schools and the community; and (c) to educate society through teachers and students.

Water Management in Organizations (Corporate Management of Water and the Environment): an instrument for water and environmental management systems for companies of all sizes that are looking for support for structuring, operating and maintaining their water management systems. The program aims to increase and qualify the supply of specialist service companies, both in the task of raising the awareness of workers and mobilizing them, as well as in choosing technologies that save water, combat all types of waste and treat liquid effluent while looking after quality, productivity and competitiveness.

In addition to raising awareness and educating the population to incorporate new water consumption habits, sector professionals (project architects, including architects, installers, construction companies and technical assistance professionals) and those responsible for managing water demand in buildings need training in the efficient use of water.

3. International experience in demand management

In consideration of the scarcity of water, various countries have dealt with the issue of demand management. The objective of this item is to present some of the international experiences.

The United States, in addition to facing a water shortage in certain regions in the country, finds itself among the group of the world's three largest consumers of water[8] due to the great demand that exists in its conurbations. New York City, for example has had policies for efficient water use since 1989, when the New York City Council prohibited the sale of high-flow showers and faucets. The first program for substituting components started in 1994. Between 1994 and 1997, 1.3 million traditional toilets were replaced by toilets with a 6 liter discharge. According to the United States Environmental Protection Agency (EPA), US$ 393 million were invested in the toilet replacement program, which reduced demand and sewage generation by 342 million liters a day, approximately 4 m^3/sec. At the beginning of 2014 a new program was launched that will last two years and that supplies a

[7] Available at: <http://www.aguaecidade.org.br/>.
[8] <www.waterfootprint.org>.

grant of US$125 for substituting old toilets for new, highly efficient toilets. The New York City Department of Environmental Protection (DEP/NY) predicts that this program will save more than 0.43 m^3/sec.

There are various programs in the United States for encouraging the replacement of components. The United States Environmental Protection Agency (EPA), in a partnership with Water Sense, for example, makes research and a selection of rebate programs available that are directed at the efficient use of water, considering faucets, discharge valves, showers, toilets, urinals and garden irrigation systems in various states.

This also happens in other countries. In the Province of Alberta, in Canada, there is a program for residential users that reimburses up to $150 when new toilets are acquired that have a 6 liter discharge rate or less, if the toilets that are to be replaced were made before 1995, or if they consume more than 6L/discharge. The costs, however, are not only associated with the purchase of the toilet, but also with the accessories and installation service of the equipment. Reimbursement comes via a credit in the water bill. For commercial consumers the reimbursement is $90 for each toilet replaced under the same conditions as the residential program.

Australia, which is located on the driest inhabited continent on the planet, had a high *per capita* consumption of more than 300 L/ per person per day in 2000, according to the Department of the Environment. The country's government offers a great range of incentive programs for replacing components. The State of Victoria, for example, reimburses $100 for dual-flush toilets, $20 for efficient showers and bidets, $1300 for rainwater tanks for use with toilets and $150 for hot water recirculation systems.

The financial incentives of component programs are commonly offered either through discounts when acquiring products or by the component being supplied free of charge. In cases in which the equipment is acquired by the consumer, the discount may be given through supplying a voucher or reimbursement after proof of purchase. In either of the cases, the component that is bought must follow the program criteria.

There are other initiatives that deserve to be stressed. The DEP/NY launched a demand management plan that aims to reduce water consumption by 190,000 m^3/year. This program is based on five strategic plans: an efficient municipal use program aimed at efficient residential use; a non-residential efficient use program; improvements in water distribution systems; and a contingency plan for when there is a water shortage. The DEP/NY also offers guidance on the efficient use of water on its website.

On the west coast of the United States, the California Water Code demands that water utilitiies that directly and indirectly serve more than 3000 consumers must prepare urban use management plans at least once every five years. These plans must also deal with demand management actions.

4. Recommendations of actions for structuring water demand management in cities for public sustainable development policies

When the domestic use of water is considered, in other words, the water used in buildings, the potential for reducing consumption through specific programs is significant. Efficient water use will be achieved through institutional actions, regulation, technology and the awareness-raising and training of users and sector professionals. The following items in this document provide recommendations, the objective being to contribute to the planning and implementation of integrated and long-lasting public policies, with a focus on existing and yet-to-be-built buildings in urban centers.

Measures directed at water demand management in Brazil require progressive introduction processes, with adaptation criteria and actions that are based on state-of-the-art technology and on public interest, and concessionaire and consumer points of view. The proposed organizational structure must be sufficiently flexible to consider the specificities and conflicts that may emerge from conservation actions in general, with an emphasis on the role of regional plans and codes of practice as preferential instruments for planning integrated and technical standardization actions. The latter are linked to quality programs that include efficient water use products and processes. Program planning must consider short, medium and long-term actions, in such a way as to direct the necessary investments in a suitable, progressive and long-lasting way.

As a general structure, it is recommended that a national program should be strengthened, which is coordinated by federal public administration, jointly with sector agents, society entities and teaching and research institutions, with its main actions centered on institutional development. Direct water demand management actions, from collection to final consumption, which come under federal, state and municipal spheres, take place in conjunction with the public and private entities involved and with sector entities and society.

In emergency situations, such as the one in the State of São Paulo, for example, measures of a temporary nature are taken, their objective being to try and control and balance an extreme situation. An example of this is the bonus offered by *Sabesp* to consumers who managed to reduce water consumption, or the incentive for using artesian wells, as a way of reducing demand on the utilitiy. Such measures will have a temporary effect on reducing consumption (the coming summer rains may reduce user efforts) or may lead to health risks for the population (the spread of artesian wells without any control over water quality).

The conservation of water in building systems considers programs and actions directed specifically at buildings, like the modernization of water systems in old buildings, programs for changing toilets and other initiatives.

Through publicity, tariff stimuli and/or tax incentives, government can persuade consumers and establish programs for supporting them in their choice of technically effective options and of skilled service providers, thus helping regulate the market and inhibit the proliferation of innocuous or harmful solutions.

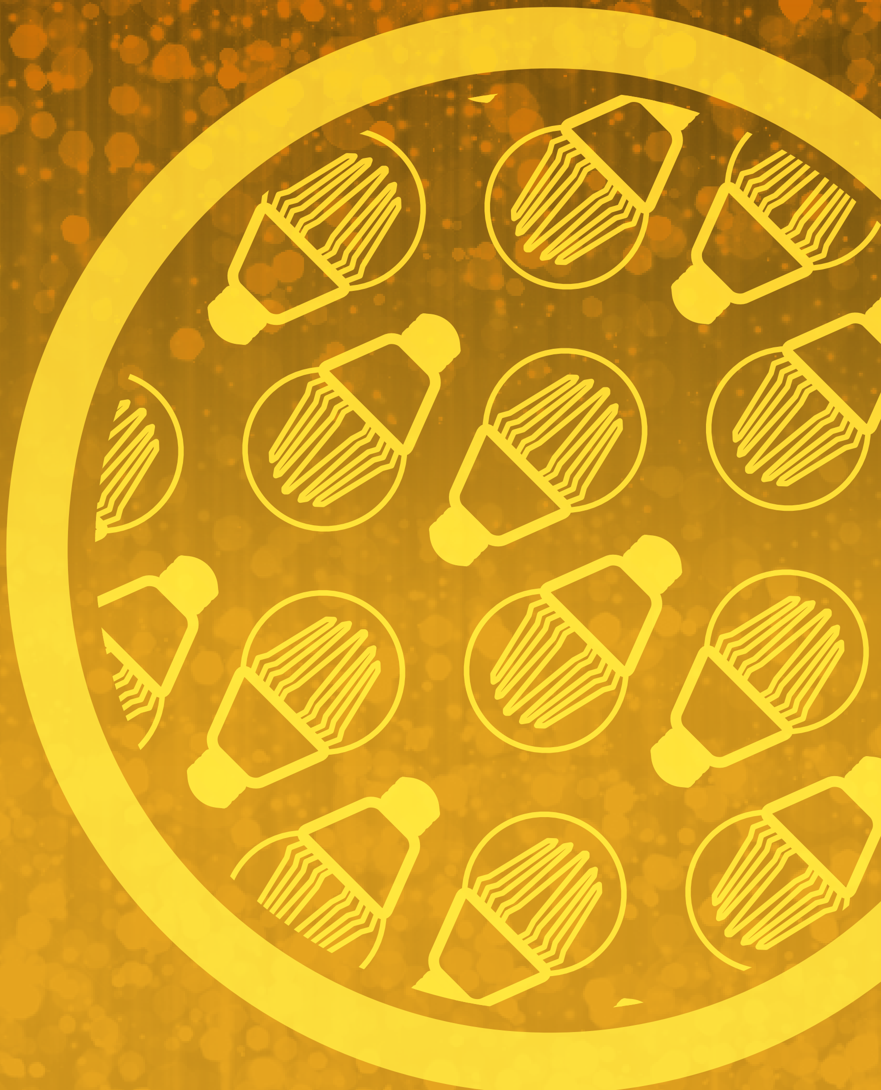
	Institutional actions	Impact
1	Update, expand and implement existing institutional programs for managing water demand – *PNCDA* and *PURA* – by integrating the actions in the three spheres of government, with support from private agents.	High
2	Implement regional and municipal water conservation plans that establish a reduction in water loss indicators in networks and a reduction in water consumption in buildings, as a condition for obtaining financing.	High
3	Promote tax and tariff incentive programs for companies that produce components and services and that take part in projects related to water conservation.	High
4	Resume and reinforce pacts between government institutions and public and private entities within already existing programs.	High
5	Prepare model Water Conservation Practice Codes (like the International Building Code (*), USA), which can guide state and municipal governments in their programs, financing, building codes and the design and construction of buildings.	High
6	Include the area of sanitation in the *CTECH* (National Housing Technological Development Committee) inter- ministerial committee, which is coordinated by the Ministry of Cities, with effective participation in the *PBQP-H* (Brazilian Housing Quality and Productivity Program).	High
7	Map out and identify regions and buildings by type that have the greatest potential for reducing consumption for establishing priorities when introducing programs for the efficient use of water.	Medium
8	Improve the institutional and legal framework (laws, decrees, regulations, ordnances and standards).	Medium
9	Promote interaction with other institutional programs, especially energy, solid waste, education and health.	Medium
10	Develop a new tariff model that is linked to a reduction in water consumption that guarantees the financial health of service providers.	Medium
11	Promote financing programs for products and services aimed at companies that take part in technological innovation, quality and sustainability projects.	Medium
12	Expand the reach of the collection of data from *SNIS* with the inclusion of building consumption and “savings” information of different types.	Low

(*) International Building Code (IBC) of the International Code Council (ICC), an association that is dedicated to developing the model codes and standards used in the design, construction and compliance process for building safe, sustainable and affordable structures. Its recommendations are followed by most of the communities in the USA.

	Technological actions	Impact
13	Plan and introduce programs for modernizing water systems in buildings that are over four stories high for the efficient use of water. The objective is to eliminate losses and waste caused by old equipment, control pressure and flow, and instal consumption metering systems for making it feasible to manage demand.	High
14	Plan and introduce programs for replacing and adapting equipment (changing toilets, installing aerators and other measures) for houses and buildings up to 4 stories high.	High
15	Stimulate and encourage partnerships between universities, research centers and industry to develop technologies that favor the conservation of water, such as: even more efficient hydraulic commands and toilets, efficient showers and bidets, integrated sewage systems, remote metering by sector, individual water metering in residential buildings and office blocks, the detection and correction of physical losses in building systems for reducing risks coming from the stagnation of water in the system; taking safe advantage of non-drinking water, by including new basic materials and electronics; new construction solutions for new buildings and those already in operation, by transforming current assembly activity processes; water consumption management models.	Medium
16	Encourage research into district systems for distributing non-drinking water, with centralized management of the operation and maintenance.	Low

	Quality and sustainability actions	Impact
17	Strengthen and expand *PBQP-H* programs to guarantee the quality of construction products and services, with a special focus on water systems in buildings; combat non-compliance.	High
18	Strengthen and expand the *PBQP-H* technical assessment program to guarantee the quality of non-standardized products, including as far as concerns their maintenance and replacement, with a special focus on water systems in buildings.	High
19	Strengthen and expand the processes for reviewing the regulations and standards that guide the conception, design and construction of new buildings, with a special focus on building water systems.	Medium
20	Establish a database with information about technologies for saving water and consumption indicators by type, characterized throughcase studies that consider the region, consuming activities and types and number of users, etc.	Medium

	Awareness-raising and professional training actions	Impact
21	Introduce programs for the efficient use of water by establishing long-lasting practices – a focus on demand management; encourage the definition of water managers and establish responsibilities for the maintenance of consumption indicators at levels that are compatible with the types of building and water use.	High
22	Establish partnerships with organizations for raising the awareness of the population as to the need to create new water consumption habits, with priority being given to long-lasting actions like those carried out in schools.	Medium
23	Encourage the implementation of training and professional recognition programs, in a partnership with associations of project architects and in stallers and with universities, with a focus on training, qualification and certification in order to guarantee the quality of service providers; continuing education programs.	Medium
24	Introduce a permanent program for managing demand in public institutions as a way of encouraging the creation of new consumption habits.	Medium
25	Develop structured programs for raising user awareness, involving third sector entities; education programs on the rational use of water that promote the introduction of monitored actions in different types of building, with the purpose of raising awareness and training operators in demand management.	Medium



PART II

ENERGY

1. Introduction

Buildings and the built environment are the largest final energy consumer worldwide; in Brazil, the sector represents 48.5% of the country's electricity consumption. As well as rising energy costs and the fact that fossil fuel reserves are finite, the IEA (International Energy Agency) states that the buildings sector must reduce CO_2 emissions by 77% by 2050 in order to avoid disastrous climate change and maintain global warming below 2°C (IEA, 2014). As the majority of anthropogenic emissions come from energy generation, energy efficiency in buildings is rapidly gaining recognition as a key sector that must be prioritised.

In the built environment and civil construction, focus of this document, energy consumption occurs in four principal stages:

- extraction, fabrication, production and transport of raw materials and building components;
- direct energy use during construction;
- operation of buildings and the built environment; and
- demolition and end of life.

Clearly, considerations of material and energy in construction are closely interlinked, as a life cycle analysis of a building must consider embodied energy in materials. (In unconditioned or highly efficient buildings, this embodied energy could be the dominant impact in the lifecycle of the building.) In this document, consumption of energy in raw materials and buildings components (the first area) is evaluated in the Materials chapter. Energy consumption in construction and demolition is relatively small compared to operational energy use; it is often poorly documented and little data is available. This chapter shall focus explicitly on the third area identified above, representing operational energy consumption during the lifetimes of buildings. The term "energy in buildings", in this document, shall refer explicitly to this stage of energy consumption.

Efficient use of energy

Energy is used in buildings to provide basic services to the users, generally including thermal comfort, lighting and data processing. The demand for these services will vary depending upon the local climate and expectations of the users. The principal focus of this document is the efficient use of energy, identifying the most effective ways of providing the required services and meeting the demands of building occupants with reduced consumption of external energy resources. The strategies considered include distributed energy generation on buildings, but not supply-side solutions.

The IEA states that the avoided energy consumption in member countries in 2010 (through energy efficiency) was greater than the additional energy production of any single source, including oil, gas and electricity. Based on these figures, energy efficiency is described as the "first fuel". Improved efficiency in the use of energy brings associated benefits; the IEA identifies 15 key areas in their analysis of the multiple benefits of energy efficiency, as shown in Figure 13 (IEA, 2014). The international initiative "Sustainable Energy For All" (SE4All) targets a doubling of the rate of improvement of energy efficiency (SE4All, 2013). Both the IEA and SE4All show the greatest potential to be in energy use in buildings. Aiming to fulfil this potential, European countries are already proposing requirements on new buildings to be Net Zero Energy, remaining grid-connected but producing all the energy they require over the course of the year.

FIGURE 13 – BENEFITS OF ENERGY EFFICIENCY

SOURCE: IEA (2014)

However, there are still significant barriers to large-scale implementation of energy efficiency in buildings. Higher initial costs (in some cases) increase capital investments required. Consumer awareness campaigns must stimulate demand, and professionals be trained to meet adequate standards. Solutions must be developed for the "Split Incentive", whereby building owners would invest in energy efficiency measures, but have no fiscal incentive as all the benefits would go to the occupant. It is clear that the development of public policies will have an important role to play in overcoming these barriers.

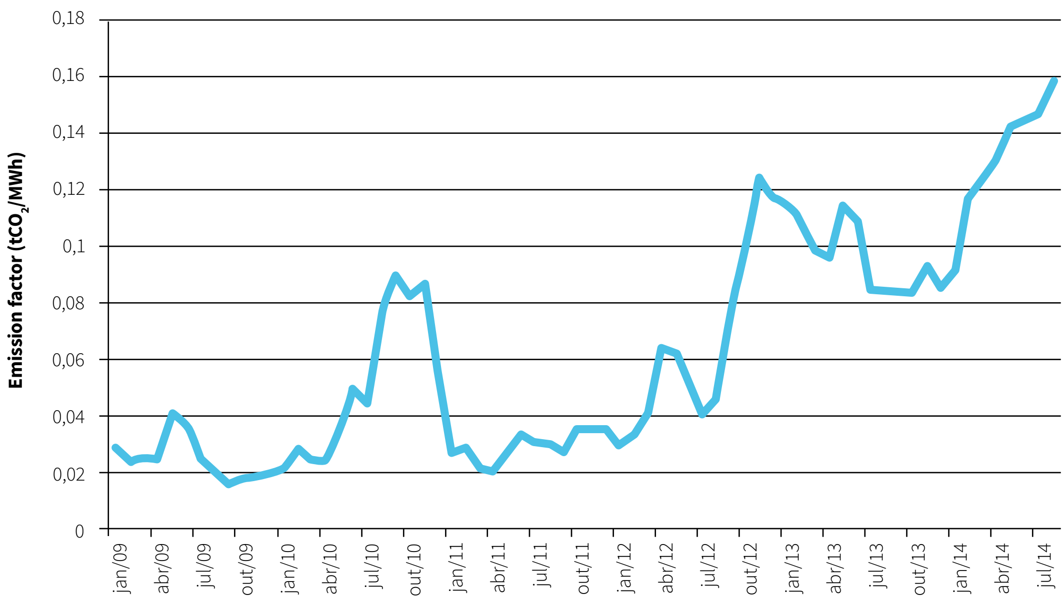
Brazilian law 10.295/2001 states that "The executive branch of government shall establish maximum energy consumption levels, or minimum energy efficiency standards, for energy consuming machines and equipment manufactured or sold in the country, based on relevant technical indicators". This provides the legal framework for a national policy on energy conservation and the majority of the measures proposed in this document.

Evolution of the Brazilian energy sector

The energy sector in Brazil is currently facing a challenging situation. A politically motivated subsidy reduced electricity costs at the start of 2013 through *Medida Provisório* 579 (which later became law 12.783/2013); at the same time a drought in south-east Brazil has restricted hydroelectric generation and required the continual, year-round use of fossil-fuelled power plants, which have a higher marginal cost of generation and traditionally were used only in dry periods and demand peaks.

These two factors have resulted in a hike in the costs of energy generation – which have not yet been passed on to the consumers – and a sharp spike in the CO_2 emissions of the sector. Data from the Ministry for Science, Technology and Innovation (MCTI) show that the mean annual carbon factor for electrical generation was 0.029 tCO_2/MWh in 2009, but rose to a peak of 0.158 tCO_2/MWh in August 2014 (the most recent month for which data were available at the time of writing) (BRASIL, 2014).

FIGURE 14 – AVERAGE MONTHLY CO_2 EMISSION FACTORS WITH THE GENERATION OF ELECTRICITY IN THE BRAZILIAN GRID SYSTEM (*SIN*) FROM 2009-2014

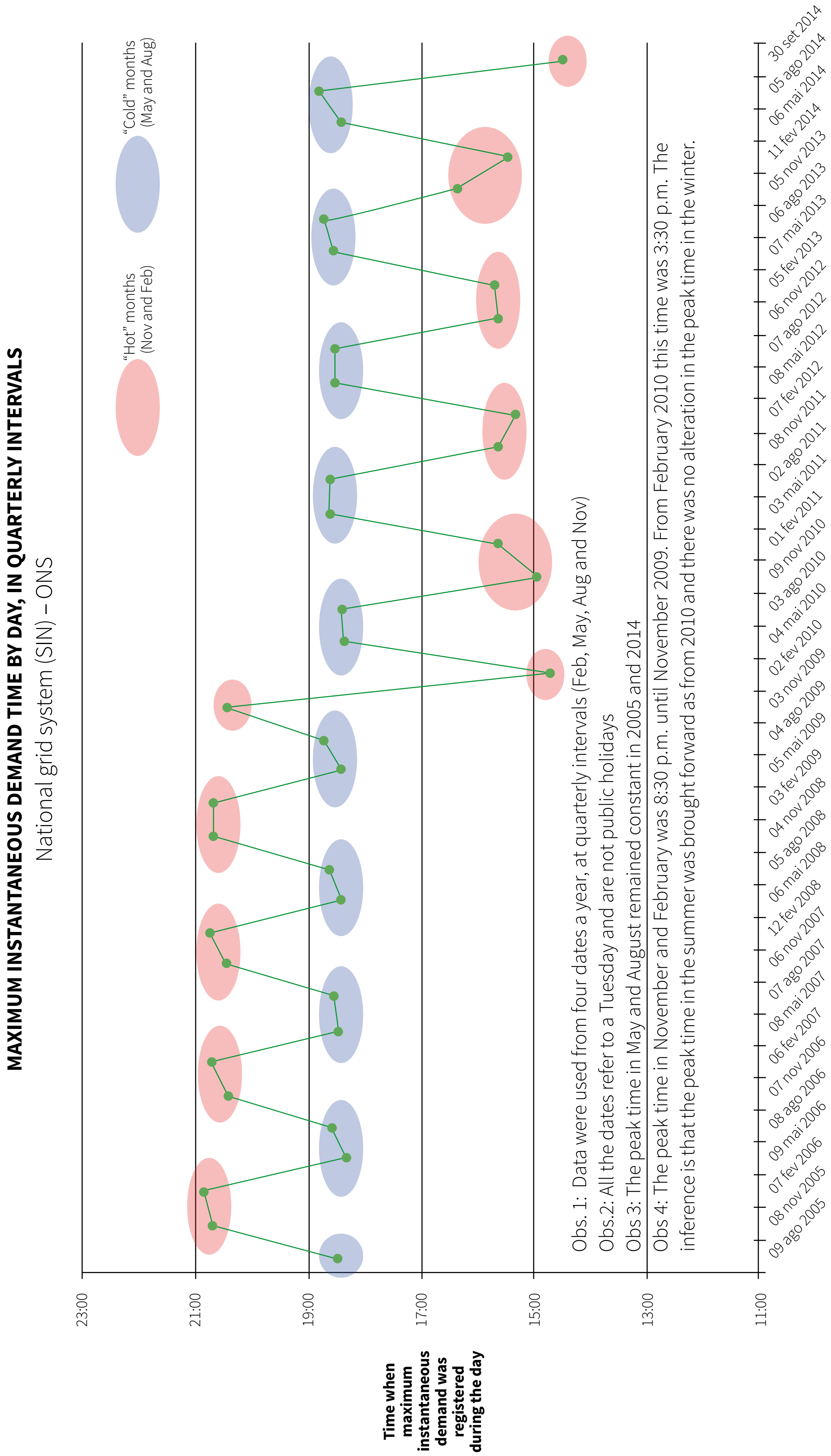


SOURCE: BRASIL (2014)

It is important to note that although the causative factor may be temporary, the long-term trends for the electrical sector shows large increases in energy consumption, increased variability of rainfall and greater use of thermal (fossil-fuelled) generation. In general terms, it is safe to assume that electrical energy in Brazil will continue to become more expensive and dirtier in the coming years.

At the same time, the electrical distribution system has seen a change in the time of peak demand. This has generally been in the early evening (dominated by electrical water heaters and lighting). At a national level, since 2010 the highest peaks in summer months have occurred in mid-afternoon (as shown in Figure 15). The proposed *Tarifa Branca* and a "flag" system for varying peak times for charging for electricity consumption will give more flexibility for the utility companies to pass real costs on to the consumers.

FIGURE 15 – CHANGE IN PEAK TIMES IN *SIN*



SOURCE: CBCS, with data from the ONS (2014)

Finally, the National Energy Efficiency Plan adopts a target energy efficiency improvement of 10% compared to a baseline scenario; this would require annual energy consumption reductions of 106,623 GWh by 2030 (EPE, 2014a). For comparison, in 2013, the energy consumption reductions quoted by the national electrical energy conservation programme Procel was 9,097 GWh, and the total reductions achieved by the utility energy efficiency programmes was 3.800 GWh. There is a clear requirement for new strategies, as these two programmes would have to multiply their impact by a factor of nine to achieve the proposed reductions.

Objectives of this study

There is a clear need for public policy and programmes to overcome the barriers to achieving the potential of energy efficiency, especially considering the societal and economic benefits associated with the reduction in the need for increased generation capacity.

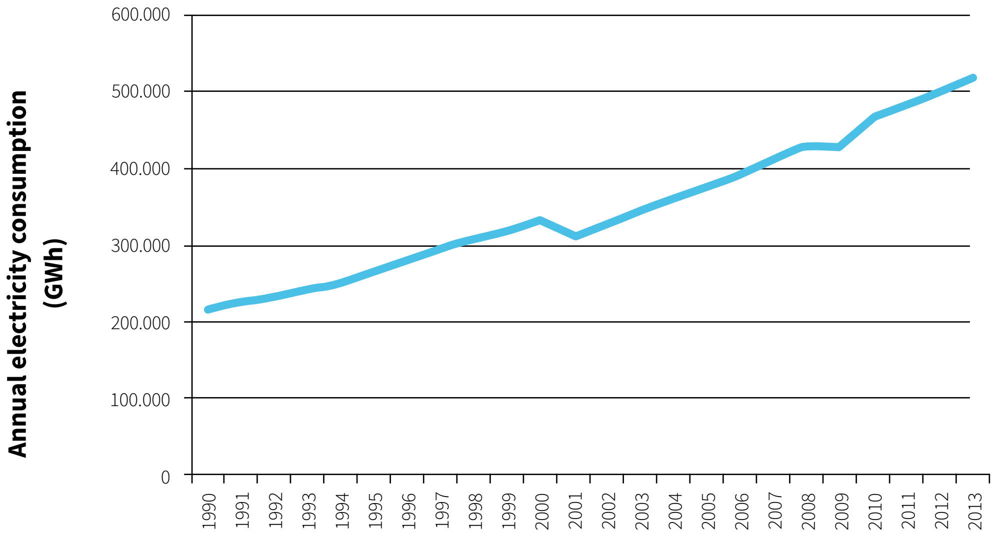
This study provides a brief evaluation of the current state of play of energy in sustainable construction in Brazil, as well as a few key international examples. It aims to provide supporting information for the elaboration of a national policy on sustainable construction.

2. National evaluation

Energy and the built environment

Energy consumption in buildings has shown consistent growth in recent years, and the National Energy Plan for 2050 (EPE, 2014a; EPE, 2014b) forecasts continued growth in consumption. Currently, the buildings sector (divided into residential, commercial and public buildings) represents 48% of the national electrical consumption (EPE, 2014a). Within the trends of increased energy consumption, the only significant reduction occurred following the energy crisis of 2001, when significant demand reduction programmes were implemented across the country. (There was also a stabilization of consumption during the world financial crisis of 2008, but growth resumed the following year.) Figure 16 shows that the energy efficiency measures taken following the 2001 crisis held back the growth in demand, avoiding an “equivalent” growth of over two years.

FIGURE 16 – ELECTRICITY CONSUMPTION IN BRAZIL, 1970–2013



SOURCE: CBCS (2014)

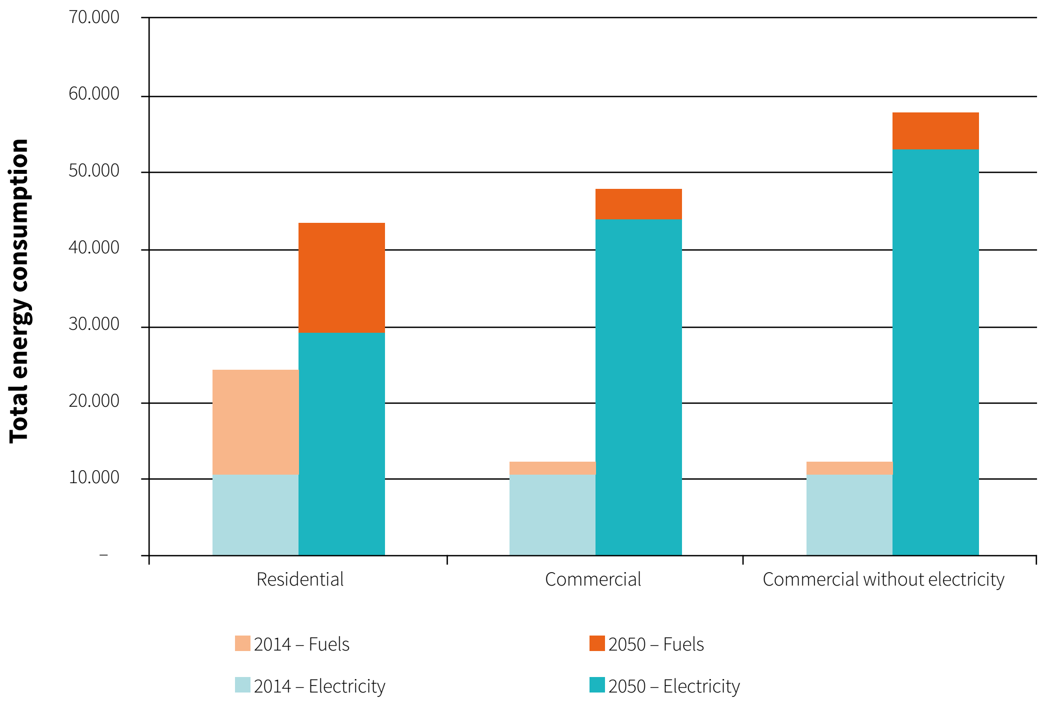
In domestic buildings, growth in energy consumption is a result of net population growth, reduction in household size and increase in the energy consumption of each household (generally associated with increased wealth). There are currently 63 million dwellings in Brazil, with total electrical consumption of 124 TWh, representing 44% of the residential final energy consumption (the rest being supplied principally by natural gas, LPG and biomass). Forecasts for 2050 show a total of 98 million dwellings, with total electrical consumption of 336 TWh, which will represent 67% of final energy consumption.

In the services sector, which includes both commercial and public buildings, it is more difficult to estimate the size of the building stock or the increases in construction. The current electrical energy consumption (89% of total final energy consumption) is 128 TWh, and forecasts show an increase to 615 TWh by 2050, representing 92% of the final consumption of the sector.

With the inclusion of non-electrical energy consumption, principally natural gas, LPG and biomass, total final energy consumption is 12,373 toe in the services sector and 24,095 toe in the residential sector. By 2050, consumption is estimated to be 47,465 toe in the services sector and 43,237 toe in the residential sector, as shown in Figure 17.

It is important to highlight that without the assumed impact of energy efficiency programmes, the services sector energy consumption would be 57,440 toe, and it would become necessary to generate an additional 106.7 TWh of electrical energy per year. The assumed reduction represents 17% of total energy consumption, but the National Energy Plan for 2050 does not clearly identify the routes for this proposed reduction of energy intensity. Two examples are given (efficient public lighting and energy labelling of new buildings), which between them represent only a very small fraction of the required efficiency improvements.

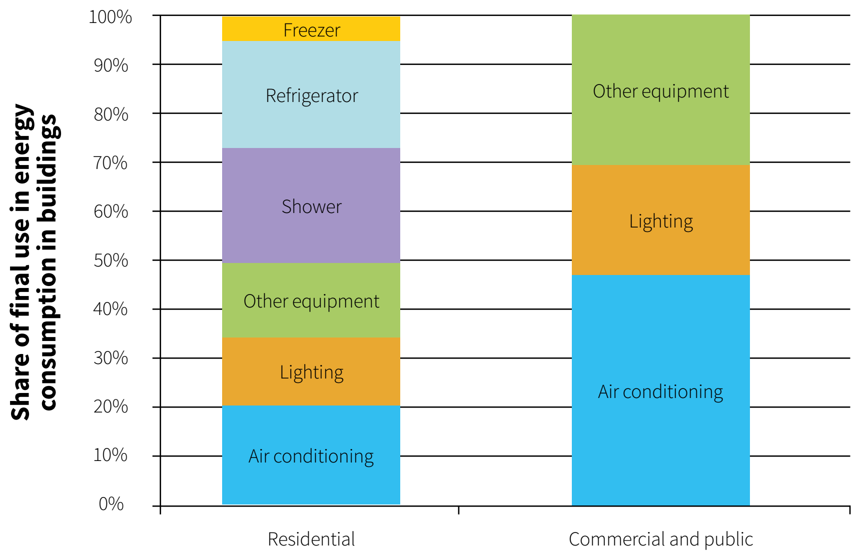
FIGURE 17 – FORECASTS OF THE INCREASE IN ENERGY CONSUMPTION IN BUILDINGS



SOURCE: CBCS, with data from the EPE (2014a; 2014b)

Comparisons with historic studies on energy consumption in buildings in Brazil show that the past decades have seen improvements in the efficiency of air conditioning and lighting systems (ELETROBRAS, 1989), but that this has been offset by much larger growth in demand for energy services, especially IT and electronic appliances. The only available data on energy consumption in buildings by end-use were published in a study on possession and use of energy consuming equipment, carried out in 2005 (ELETROBRAS, 2007). It is likely that the data collected are now obsolete, as there have been significant changes in consumption profiles during the past decade, especially in the residential area, and this study should be updated.

FIGURE 18 – ENERGY CONSUMPTION IN BUILDINGS BY END USE



SOURCE: CBCS, with data from ELETROBRAS (2007)

The data available on energy consumption in buildings separate energy in commercial and public buildings into air conditioning, lighting and office equipment, while residential consumption is dominated by electric shower heads (for water heating) and refrigerators.

Climate change is also having an important impact; in many cases, it has increased the frequency and intensity of extreme weather events, such as droughts or heatwaves. The combination of these impacts with urban heat island effects (from increased urban density) can have important results. For example, a heatwave in February 2014 resulted in a sharp increase in the installation of residential air conditioning units; in turn, the electrical distribution system registered several new records for peak national system demand (at some points, records were broken in several sequential days) (ONS, 2014).

Trends in building design and construction

Commercial buildings have seen rapid growth in IT and electronic equipment loads, as well as a more recent increase in the complexity of building services and systems. The Green Building trend has brought principally American models for sustainable building and energy consumption in buildings, following international standards. This generally requires fully conditioned spaces, and an evaluation of the state of the art in efficient construction states that "the mistaken selection of building designs and construction methods imported from other countries and implemented in the Brazilian climate has resulted in a buildings sector that does not adapt naturally to local climatic conditions and increasingly requires the use of artificial space conditioning, leading to the unnecessary use of energy and natural resources (PESSOA, 2013b).

Historically, Brazil has had a strong tradition of bioclimatic architecture and the design of buildings that guarantee thermal comfort by natural ventilation or the use of "mixed mode" strategies, with air conditioning only switched on when necessary. However, demands from the commercial sector are moving away from this model, and current building designs are increasingly dependent on active, energy-consuming systems. Brazil is already the fifth largest buyer of air conditioning systems in the world, considering window and split systems

(PERIRA, 2013), and this consumption is growing rapidly. In this context, close control of the performance and efficiency levels of these systems and technologies is needed.

The main energy consumers in residential buildings are cooking, lighting and water heating. However, data from the National Energy Plan for 2050 (EPE, 2014a) forecast changes in consumption profiles. Increased use of natural gas and solar water heaters should reduce electrical consumption in this area, while the use of biomass for cooking should also decrease and be replaced by LPG and natural gas. At the same time, the use of air conditioning systems will rise sharply, with ownership levels going from 0.23 per household today to 0.65 per household in 2050. Even assuming continued increase in the energy efficiency of these systems, this will result in sharp growth in demand from the sector. Growth in consumption will be dominated by increased air conditioning and electronic goods (principally entertainment systems) in the following years.

The Performance Standard for Dwellings (NBR 15575/2013) imposes, for the first time, minimum criteria for the thermal performance of new dwellings. The requirements are not highly restrictive, but are already resulting in changes in the construction market.

Air conditioning standards are being reviewed to include models of adaptive comfort, relevant for environments with natural ventilation and modelling the impacts of giving occupants localized control over their environment; this should permit air conditioning system designs to be less conservative.

In social housing, the My House My Life programme (MCMV) has required the installation of solar water heating systems in all single family houses built since 2012. Despite problems with some of these systems, they bring clear energy consumption reductions in regions of the country that have traditionally heated water for washing. However, in hotter regions of the north and northeast of Brazil, the installation of these systems has changed traditional habits (before these systems, people typically had cold showers); in this case, the installation of solar water heating has improved the comfort of homeowners but has not necessarily resulted in any improvements in energy efficiency.

Operation, maintenance and retrofit

Growth in the use of complex technology in building services has increased the difficulty of operation and maintenance of newer buildings. The profession of Facilities Manager is relatively recent in Brazil and has resulted in the formation of associations such as ABRAFAC to try and meet these needs. As many commercial buildings outsource their maintenance, the building operators and administrators do not always have the know-how necessary to optimise energy consumption; this makes it more difficult to implement energy efficiency measures.

Towards the end of the 1990s, with the increased visibility of green building in the UK, the first studies noted the emergence of a “performance gap”, a difference between the as-designed energy consumption and real, measured values during occupation. This is a highly significant area, and merits close attention to ensure that energy efficiency measures produce the promised results. Studies in the UK show real consumption 50-150% higher than design estimates (CARBONBUZZ), while the first data on certified Brazilian buildings show 50% increases in many cases. These results highlight the importance of measuring and reporting operational energy performance to ensure that buildings are correctly operated.

Another important area for public policy is building retrofit. The reoccupation of old city centers and the refurbishment of buildings from the 1960s and 1970s (such as those on Avenida Paulista, in São Paulo) will significantly increase this type of work. Building retrofit represents an important opportunity for improving energy performance.

Distributed energy generation

Distributed generation of energy is considered highly important in the forecasts of the National Energy Plan for 2050 (EPE, 2014a), and the Normative Resolution 482/2012 of the National Electrical Energy Agency (ANEEL) permits and regulates connection of microgeneration systems to the national grid.

As of October 2014, data from ANEEL show that there are 165 microgeneration systems connected to the national grid; the majority are small-scale photovoltaic systems. However, rapid growth will be needed for this type of system to have any importance at the national level in the coming decades.

Labelling and certification programmes

Brazil has several different schemes for energy performance labelling and certification of individual pieces of equipment or entire buildings; this some are mandatory and others voluntary.

The Brazilian Labelling Programme (PBE) and the Selo Procel define minimum performance levels for significant energy consuming equipment, such as refrigerators, ceiling fans, light bulbs and residential air conditioning systems.

The PBE Edifica labelling scheme defines levels of energy efficiency for buildings. Implementation of PBE Edifica has been through voluntary adoption on the market, but the Normative Instruction 02, published on the 4th June 2014 by the Ministry for Planning, obliges new and retrofitted federal public buildings to label their energy efficiency and to achieve a level A on the PBE Edifica scale.

Since 2007, sustainable building certifications have gained prominence in the construction sector in Brazil, especially in the high-end sector. It is estimated that in 2012, buildings registered for sustainability certifications represented 9% (by value) of the civil construction market (ERNST & YOUNG, 2013). Brazil has prominent international certifications, especially LEED (USGBC, 2014), and local adaptations of international certifications, such as the AQUA (High Environmental Quality) programme, developed by the Fundação Vanzolini (FUNDAÇÃO VANZOLINI, 2014). Several sector-specific schemes have also been developed, such as the Selo Qualiverde in Rio de Janeiro, Selo BH Sustentável in Belo Horizonte and the Selo Casa Azul, developed by the Caixa Econômica and aimed at social housing.

In many cases, certified buildings are the largest energy consumers, due to their high specifications and the use of international standards. It is not clear that these voluntary certifications guarantee energy saving; the only study carried out in Brazil (OLIVEIRA, 2014) shows that LEED certified buildings consume slightly more energy than buildings of the same type and use which have not been certified. Similar results have been obtained in the USA (NEWSHAM, 2009; SCOFIELD, 2013). It is important to note that environmental certifications may bring benefits in several other areas, and that these programmes have had significant positive impacts on the construction sector as a whole. However, the results cited above show that these certifications used in isolation may not be an adequate tool for guaranteeing energy efficiency.

TABLE 7 – MAIN CERTIFICATES OF SUSTAINABLE CONSTRUCTION IN BRAZIL

Main voluntary certificates of sustainable construction			
Name	Reach	Market knowledge	Reference for EE
LEED	International	High	ASHRAE 90.1
BREEAM	International	Low	Variable
AQUA	Brazil	High	PBE Edifica
Blue House Seal	MCMV	Low	Qualitative assessment
PBE Edifica (Procel)	Brazil	High	PBE Edifica
Qualiverde Seal	Rio de Janeiro	Low	Qualitative assessment
House Reference	Brazil	Low	PBE Edifica
BH Sustentável Seal	Belo Horizonte	Low	Qualitative assessment

Financing energy efficiency

In Brazil, there are two main dedicated sources of finance for energy efficiency projects. The PROESCO fund of the BNDES (National Development Bank) specifically supports energy efficiency, and the utilities' Energy Efficiency Programme (run by ANEEL) obliges generation and distribution companies to invest a minimum of 0.5% of their turnover in energy efficiency.

The Energy Efficiency Guarantee Mechanism (EEGM) supplies a methodology for insuring the expected savings from energy efficiency projects; theoretically, this should increase the use of energy performance contracting and overcome one of the principal barriers to development of the sector (EEGM, 2014).

However, the buildings sector is highly diverse and distributed, which increases the complexity and difficulty of implementation of energy efficiency measures, which are easier to carry out in large industry, for example. The lack of trained professionals for identifying energy efficiency potential and implementing projects has limited the use of energy performance contracting and held back energy efficiency development generally.

3. International policies for energy in buildings

Introduction

Given the great importance of the energy in buildings sector, there are a wide range of policies under development and being implemented internationally. The IEA (IEA, 2011) identifies 25 recommendations for policies for energy efficiency (Figure 19), and has recently published sever other studies to support the development and implementation of such policies, especially for energy in buildings (IEA, 2009; IEA, 2010; IEA, 2013-1; IEA, 2013-2; IEA, 2013-3).

FIGURE 19 – PUBLIC ENERGY EFFICIENCY POLICIES

CROSS-SECTORAL

1. Data collection and indicators
2. Strategies and action plans
3. Competitive energy markets, with appropriate regulation
4. Private investment in energy efficiency
5. Monitoring, enforcement and evaluation

BUILDINGS

6. Mandatory building codes an MEPS
7. Net-zero energy consumption in buildings
8. Improved energy efficiency in existing buildings
9. Building energy labels or certificates
10. Energy performance of building components and systems

APPLIANCES AND EQUIPMENT

11. Mandatory MEPS and labels
12. Test standards and measurement protocols
13. Market transformation policies

LIGHTING

14. Phase-out of inefficient lighting products
15. Energy-efficient lightning systems

TRANSPORT

16. Mandatory vehicle fuel-efficiency standards
17. Measures to improve vehicle fuel efficiency
18. Fuel-efficient non-engine components
19. Eco-driving
20. Transport system efficiency

INDUSTRY

21. Energy management
22. High-efficiency industrial equipment and systems
23. Energy efficiency services for SMEs
24. Complementary policies to support industrial energy efficiency

ENERGY UTILITIES

25. Utility end-use energy efficiency schemes

SOURCE: IEA (2011)

Tools and policies for energy in builings

The Global Building Performance Netowrk (GBPN) is an international organization that brings together and publishes technical information, as well as supporting the development of energy efficiency in buildings. Among other tools, the GBPN have created the BuildingRating.org portal (GBPN; IMT, 2014), which lists policies implemented in different countries and states. The American Department of Energy (DoE) has its own portal, EnergyCodes.gov, which supports the development of minimum efficiency standards for construction, and the Building Performance Institute Europe (BPIE) publishes recommendations for the implementation of labelling and certification programmes. The International Partnership for Energy Efficiency Cooperation (IPEEC) published an international evaluation of building performance evaluation programmes, classified by voluntary/mandatory implementation, asset/operational ratings and the types of buildings included (IPEEC, 2014).

The main instruments used for improving energy performance in buildings are:

- minimum performance standards;
- performance labelling and certification;
- technical support, tools and training; and
- financial incentives.

All of these instruments can be applied to whole buildings or to individual building systems. For example, energy efficiency labels can be applied to a building envelope, an air conditioning system, a solar panel or an entire commercial building. Table 8 describes the principal performance classification systems used internationally. Some are mandatory and others voluntary, depending on local legislation.

Technical support and development of tools includes the training of energy auditors and commissioning professionals; in New York, under Local Law 87, energy audits are required in some types of buildings, and this drives technical development of professionals. In many cases, technical associations and institutions are responsible for this development and training; for example, ASHRAE in the USA and CIBSE in the UK.

TABLE 8 – INTERNATIONAL PERFORMANCE CLASSIFICATION SYSTEMS

Performance classification systems, requirements, labeling and EE certification			
System	**Description**	**Application in Brazil**	**International example**
Asset rating	Assessment of the physical installations of a building and the potential for efficiency, for influencing the buy or rent decision	*PBE Edifica*	DECs – United Kingdom
Operational rating	Measuring energy consumption in order to assess the performance in operation, support efficient management and identify failings	n/a	EPCs – United Kingdom
Transparency Law	Obligation on large consumers to publish energy consumption figures and efficiency levels	n/a	LL84 – New York
Building works code	Compulsory requirements for energy performance in all new constructions	NBR 15575	Building Regulations Part L – United Kingdom

Performance classification systems, requirements, labeling and EE certification			
System	**Description**	**Application in Brazil**	**International example**
Minimum energy performance for equipment (MEPs)	Minimum requirements for energy performance in certain equipment	PBE	EU Minimum Standards – European Union
Efficiency labeling for equipment	Minimum requirements for energy performance in certain equipment	PBE/ Procel seal	Energy Star – USA
Voluntary building certificates	Sustainability and efficiency programs with visibility in the market, for supporting sustainable construction and showing commitment to the environment	PBE Edifica, AQUA, LEED	LEED – USA

SOURCE: Hinge (2014) and preparation by CBCS

Financial incentives can include tax rebates or direct financing; for example, by the payment of subsidies for energy generated by microgeneration (feed-in tariffs), used in many countries to incentive distributed generation from renewable sources. In these programmes, the owners of the generation system receive payments for all the energy generated, depending on the technology used. In many cases, the energy utility companies are obliged to implement energy efficiency programmes. In the long term, it is argued that energy utilities must change their business model from selling energy to the provision of energy-related services.

Example policies

Amongst the international policies studied, a few countries are highlighted for having especially effective, well-developed or innovative policies.

The European Performance of Buildings Directive (EPBD) imposes a series of obligations on member countries of the EU, aiming to improve sector-wide energy performance in buildings. Amongst these obligations is a requirement to develop public certificates of energy performance for buildings, based on primary energy. All EU member countries are developing their own ways to meet these requirements; recent studies show that the costs for a residential energy label vary from €30 to €900 per dwelling, depending on the level of detail required by the label (BPIE, 2010).

In the UK, this requirement was implemented with the use of Energy Performance Certificates (EPCs) and Display Energy Certificates (DECs), based on Asset Ratings and Operational Ratings respectively. The implementation goal identified key criteria for success of the certifications, including precision (+/- 5%), replicability (+/- 15%), credibility and ease of use; the work required for one certificate is estimated at eight man-hours for a dwelling and 16 man-hours for a commercial or public building.

France recently updated the minimum requirements for efficiency in new buildings, which now include a “bioclimatic indicator” to guarantee the use of passive strategies in construction and avoid the current focus on ever-more-complex building systems. The focus of the programme is self-sufficiency, followed by efficiency of systems, and finally distributed generation. (IEA, 2013-1).

In the USA, many building performance policies are implemented by specific municipalities or states; among them, New York should be highlighted for its innovative policy under the Greener Greater Buildings Plan. Initially, this required disclosure of energy consumption in buildings of over 5,000m²; more recently, it has also required energy audits and retrocomissioning of these buildings (PLANYC, 2014).

India has carried out scenario mapping for future energy consumption of dwellings, led by the GBPN, which indicated that by 2050 energy consumption could be eight times higher than current levels. The implementation of ambitious efficiency policies could reduce this increase to only three times higher than current levels (GBPN, 2014).

4. Proposals for future policy frameworks in Brazil

Sector issues and the importance of policy

Compared with other countries, Brazil still has relatively low energy consumption in buildings and an electrical grid with low CO2 emissions. However, this scenario is rapidly worsening, with increased energy consumption and a dirtier energy grid. Unlike developed countries, there is not yet a large stock of inefficient buildings that requires retrofitting to reach energy efficiency standards. On the contrary, there is an opportunity to maintain the current efficiency levels and improve build quality in new buildings, to avoid locking in dependence on energy consuming systems.

Firstly, there is a need for a strategic, multi-sector vision of energy efficiency. Scenario planning is needed, to clearly show the impacts of different energy policies, to overcome barriers to energy efficiency and to implement and evaluate energy efficiency policies.

The growth in the use of active cooling systems cannot be ignored, especially as their use may be avoided in a country with large populations in areas with temparate climates which should not need artificial air conditioning during most of the year. International standards generally assume space conditioning for thermal comfort; Brazil needs to recognise and incentivise the continued development of naturally ventilated and mixed-mode buildings. In parallel, the increased use of air conditioning systems must guarantee internal air quality and sufficient levels of outdoor air.

The use of energy labelling and Minimum Energy Performance Standards (MEPs) is an area of great importance, which has been developed through the PBE and the Procel programme. However, both should be expanded and receive further support.

Strategies for public policies should be clearly communicated, explaining the responsibilities of the three levels of executive power in Brazil's federative system. These responsibilities will vary depending on the policies implemented, but in general terms should be thought of as follows:

- Federal government: responsible for the publication of directives, for the development of tools and technical methodologies, for the strengthening of institutions and technical training and for financing mechanisms.
- State governments: should adapt national policies to local realities and necessities.
- Municipal governments should prioritize, implement and evaluate the impacts of policies, giving feedback to the central institutions coordinating the programmes.

To guarantee the implementation of recommendations on the market, it is important to consider the agents with large potential impacts. Of particular importance is the relationship with energy utilities, as they already have relationships with the energy consumers likely to be the targets of programmes.

Generally, in the preparation of a policy, several implementation stages should be considered:

1. voluntary implementation;
2. working with the private sector and civil society – for example, bringing an increased value proposition for participants through certification; and
3. mandatory implementation.

In general, public policy should aim to take a long-term view, to understand that investments in energy efficiency now will avoid large future investments in energy costs and increased generation capacity. To be effective, any efficiency programme must ensure that technical, technological, administrative, institutional and financial capacities are in place. In addition, research and development must be stimulated, investment and competition incentivised and case studies created to aid the transformation of the market and identify the energy reduction potential of the buildings sector in Brazil in the coming decades.

Plannning and management

NATIONAL ENERGY EFFICIENCY AGENCY

The creation of a National Energy Efficiency Agency is proposed, as this agency would be capable of developing a strategic vision for efficient use of energy and coordinating actions between different agents, including the current electrical efficiency programme, Procel. This agency would be responsible for driving actions on energy management and efficiency, planning, evaluating performance and developing and publishing technical information for the sector.

In the area of buildings, one priority for the agenc should be a study on the relationship between operational energy consumption and embodied energy in materials, to create a truly integrated policy for sustainable construction.

.PBE EDIFICA AND PROCEL EDIFICA

The PBE Edifica program was developed to certify the asset rating or potential energy efficiency of buildings in Brazil. The programme is currently voluntary, but the Normative Instruction 02, published on the 4th June 2014 by the Ministry for Planning, obliges new and retrofitted federal public buildings to label their energy efficiency and to achieve a level A on the PBE Edifica scale. State and municipal governments, as well as national agencies, should follow this example.

However, energy labelling under the PBE Edifica programme is still expensive and little-used on the market. The programme should be supported and expanded, with training, public communication strategies and accreditation of further certification agencies. Development of tools, like the S3E simulation tool (S3E, 2014) – currently passing through validation – should be supported to further reduce certification costs and make PBE Edifica a tool that can be applied to the mass-market.

The evalation structure of the PBE Edifica programme should also be adapted to create a simplified asset rating for existing buildings, which would be fast and cheap to implement, with target costs between R$500 and R$2.000 for the evaluation of a dwelling or small commercial buildings (larger, complex buildings have higher costs). Once developed and validated, this asset rating could be required for selling or renting a building. It should be stressed that the reliability of the results must be balanced against the cost of implementation, and quality should not be sacrificed.

Stock reference models should be developed, to allow macroeconomic modelling and to understand the impacts of implementation of different levels of PBE Edifica in the Brazilian market (CORGNIATI, 2013).

Finally, future climate years should be developed, considering climate change scenarios, to permit the evaluation of future impacts of energy policies and labelling programmes.

OPERATIONAL ENERGY PERFORMANCE

The development of benchmarks and baseline values of typical energy consumption in common building types should be a priority. This development involves studies and information gathering as well as the calculation of efficiency indicators and operational ratings to represent the typical consumption of the building stock (CBCS, 2014; BORGSTEIN, 2014).

Following development of the benchmarks, it will be necessary to build the necessary infrastructure for implementation of the energy evaluations and certification of operational energy performance. This will include calculation tools, online data collection tools, training of energy assessors, a database and quality assurance programmes. The programme as a whole should be developed to be cost neutral as far as possible – fees for certification of buildings and accreditation of energy assessors should provide the finance necessary for maintenance of the technical infrastructure of the programme.

DISCLOSURE LAWS

There are large potential benefits in the model of a disclosure law, which obliges publication of energy consumption and efficiency levels of large consumers. It is a policy which would probably be suited to a few large urban areas, such as São Paulo, Rio de Janeiro and other large cities. A model policy should be provided, as well as support for the necessary technical development, for adoption by the municipal governments that see the policy as beneficial.

Another route to be explored is an obligation on the energy utilities to facilitate access to energy consumption data for clients and representatives. In many cases, demand and consumption data are recorded in 15 minute intervals by the energy utility, but are not easily available for study. The improvement of this process would increase the ease of energy management in existing buildings and reduce the costs of energy auditing.

SOCIAL HOUSING

The minimum standards of the My House My Life (MCMV) programme should be updated to include climatic adaptation, thermal comfort and energy efficiency, in order to improve their performance and avoid future mass installations of air conditioning systems. Key areas are: windows and fenestration, construction materials, reflectivity of surfaces, efficient lighting and fans.

RETROFIT

The main barriers to retrofit of buildings are regulatory. For example, strict fire prevention laws make it difficult to refurbish many existing buildings. Municipal governments should seek to support and facilitate the approval of retrofit projects, so long as energy efficiency measures are considered. The PBE Edifica evaluation tools could be used to evaluate these measures.

FINANCIAL INCENTIVES

Tax exemptions or rebates have the potential to be important tools for sustainable construction. This is complicated by the division of taxes between the three levels of executive power; for example, IPI is a federal tax, ICMS is a state tax and IPTU is levied by the municipality.

Models for tax exemptions should consider these three levels; for example, IPTU reductions should be considered for buildings that meet level A of PBE Edifica. In these cases, a national programme should provide adequate third party certification or QA tools, as well as model legislation that could be adopted by municipal governments.

EXEMPLAR PROJECTS AND NET ZERO ENERGY BUILDINGS

To incentivise the sector and create references, exemplar projects should be built to showcase efficiency, technologies and distributed generation. Supporting such exemplars and obliging them to publish their energy consumption would stimulate the market and create alternative reference points to the current LEED, which does not guarantee energy consumption reduction. The projects should be carried out in different states and climati regions, and post-occupancy evaluations should be carried out. An online portal could show real-time energy consumption and production of the buildings, which would be publicised nationally.

Education: professionals and the public

STRENGTHENING TECHNICAL INSTITUTIONS

The strengthening of technical institutions and associations on the market should be supported, so that they can become platforms for expertise and act in training of professionals, the generation of know-how and the validation, implementation and review of policies. Several such institutions already exist, and generally have some contact with government.

TRAINING FOR ENERGY ASSESSORS, COMMISSIONING AGENTS AND OTHER PROFESSIONALS

Good energy management in buildings, with the use and application of benchmarks and operational efficiency programmes, requires a training programme for building management professionals, especially in newer and more complex buildings. This training should be done in parallel with the creation of exemplars and case studies for energy management.

Construction of efficient buildings requires an integrated design process, to aggregate know-how from diverse areas and optimise performance. Specifically, energy simulation should be considered as a design tool (and not a minimum compliance tool, as it is currently used). There is a need for the training of architects and air conditioning engineers in the principles of mixed-mode building operation.

With the increased complexity of building services in new buildings, large efficiency gains can be achieved by the effective commissioning of building services, and with the application of energy auditing and retrocommissioning in existing buildings. There is a need for more professionals on the market to unlock this potential.

In all these areas, Continuing Professional Development (CPD) programmes should be implemented to oblige professionals to maintain their knowledge up-to-date.

ENERGY EFFICIENCY IN EDUCATION

Universities, schools and technical training colleges will have an important role in training future generations of professionals, to make energy efficiency a key issue in all areas. There is a need to update university curricula for engineering and architecture, for example, to give these subjects more weight.

MEDIA CAMPAIGN

A national media campaign should aim to communicate the benefits of sustainable construction and energy efficiency, and showcase the tools currently available on the market, such as PBE Edifica, to motivate voluntary adoption.

Technologies

COOL SURFACES

The use of cool and reflective surfaces is one of the first priorities for envelope energy efficiency in hot climates. However, there is a need for the development of standards, tests and technical specifications referring to the useful lifetime of these materials. The development of these standards and material selection criteria are a high priority.

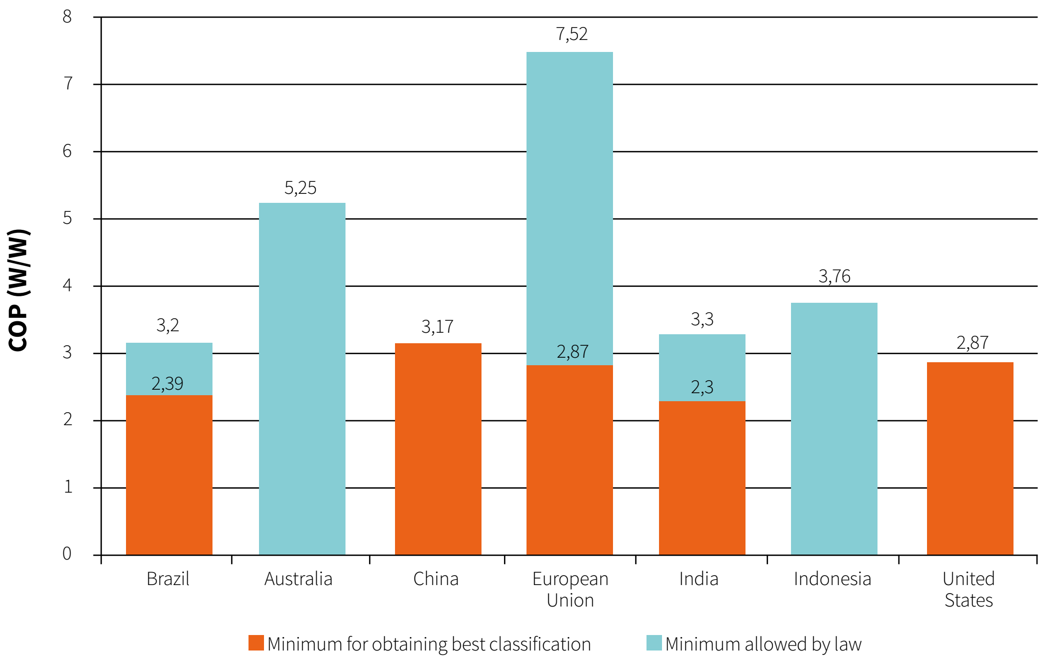
WINDOWS AND FENESTRATION

Currently, the construction market produces and markets many windows and frames with thermal performance significantly worse than systems installed decades ago. Especially in hotter climates, the installation of windows without external shading is likely to oblige the building to use active cooling systems. A detailed evaluation of the requirements of the market should be carried out in conjunction with window suppliers and producers, in order to provide more effective ways for evaluating thermal performance and selecting the best products.

AIR CONDITIONING AND VENTILATION

The widespread installation of air conditioning systems has altered peak demand for energy in the country in the past few years. Minimum performance standards (MEPs) are far below comparable levels in other countries like China, and current high levels of sales of air conditioning systems are resulting in the lock-in of many inefficient systems which will continue consuming energy for at least a decade. National MEPs should be increased as a matter of urgency in all types of air conditioning system, but especially in Split systems, which represent a large portion of the market. The technology, and many of the manufacturers, are international, so there is no reason for Brazil to be far below international standards. Figure 20 shows a comparison of international standards for energy efficiency of small air conditioning systems, based on the coefficient of performance (COP). The minimum required in Brazil (2.39 W/W) is far below the Chinese minimum of 3.17 W/W. IN addition, the level required for a level A (the highest rating in Brazil) is 3.20 W/W, far below the equivalent rating in the EU, which is 7.52 W/W (PEREIRA, 2013; CLASP, 2014; MELO, 2010; MELO, 2013; JANNUZZI, 2012).

FIGURE 20 – INTERNATIONAL ENERGY EFFICIENCY LEVELS IN SPLIT TYPE AIR-CONDITIONING SYSTEMS



SOURCE: CBCS, with data from CLASP (2014); PEREIRA (2013) and INMETRO (2014)

Minimum performance standards and efficiency labels should also be implemented for larger air conditioning systems and chillers. There should be an open discussion regarding the larger energy consumption of air-cooled chillers, compared to the high water consumption requirements of (more efficient) water-cooled chillers, in order to propose sustainability directives for different regions.

Air conditioning systems should be evaluated by the seasonal energy efficiency ratio (SEER) and not just the COP, in order to evaluate more effectively their real performance. (PEREIRA, 2013).

The use of ceiling fans can be an important thermal comfort strategy in many climates for much of the year, avoiding the need for air conditioning. Efficient systems with PBE level A should be supported as an alternative to air conditioning systems. Development of quieter and more efficient systems should be supported.

Solar cooling systems are still in the technical development phase, but show large potential for implementation in buildings where the peak demand coincides with peak solar gain. The development of prototypes should be supported.

Intelligent control systems for air conditioning is a relatively under-developed area in Brazil, but has large potential for improvement of performance of air conditioned buildings. As most systems are supplied by air conditioning manufacturers, there is little competition and many systems are not well understood and simply switched off by untrained operators. A research programme in efficient, easy to use controls could bring large benefits.

LIGHTING

Incandescent light bulbs are being removed from the market; comparative studies have demostrated the importance of this measure (MELO, 2013). New technologies – like LED lighting and high efficiency fluorescent tubes – are already widespread on the market, but their performance is variable. The NBR 5413 lighting standard was recently substituted by the NBR ISO/CIE 8995-1 (lighting of workspaces). This standard regulates illumination quality as well as lighting levels. Thus, new technologies should be evaluated by the Colour Rendering Index (CRI), colour temperature, dimmers, useful life and direction of the lighting band (PESSOA, 2013a).

Some new LED systems actually have worse performance than fluorescent systems on the market. The lighting sector has large potential gains, but the support of new technologies should be carried out carefully, evaluating all aspects of performance.

WATER HEATING

The largest potential for energy saving in water heating is the use of solar thermal heating systems.

The MCMV programme requires solar heating systems in new single family dwellings. However, there has not been effective measurement and verification of the savings and impacts – this should be carried out urgently.

As the programme has already installed around 70,000 systems (at the time of writing) and contracted a total of 218,000, there is great potential for the creation of local industries centred on the installation and maintenance of these systems. Residents of communities with solar heaters should be trained to carry out installations and maintain systems, so that they will eventually offer these services to the rest of the market and solar heating will become a standard for water heating.

In other sectors, there is still a need for technical development of solar water heating, to better understand problems, monitoring, control and interface with the users. Especially important is the existence of companies ready to carry out maintenance of these systems and avoid future problems, which may result in increased energy consumption.

Heat pumps have large potential for water heating where there is no space for solar systems. These systems are an economical alternative to electric shower heads, and the development of the technology in Brazil should be supported. The implementation will probably not be financially viable in locations with piped natural gas supplies.

PUMPS AND MOTORS

Energy consumption is directly linked to efficiency in the use of water, as pumping of potable water is a significant energy consumer. The Procel Sanear programme showed that energy for pumping is the largest operational cost of the operators of water distribution systems. In buildings, water is generally pumped to fill individual reservoirs. Pressurisation of the water network could avoid this double energy consumption, although depending on the city topography, pumping may still be necessary in some places. In Brasilia, this pressurisation has already been adopted by CAESB.

According to the SNIS, the mean losses in water supply networks in Brazil is 44%; the first step in reducing energy for pumping should be to reduce water losses. There is currently no hierarchic model for national verification of performance; the ARSESP model from São Paulo should be replicated at a national level. An integrated policy framework for energy and water would incentivise efficiency.

OTHER EQUIPMENT

There has been a rapid increase in the energy consumption of electronic goods and IT systems. PBE and Procel should be expanded to cover these areas in more details, developing minimum standards for computers, for example. As many of these systems are manufactured by international companies, there is no reason for efficiency standards in Brazil to be below those of other countries. Verification of the implementation of PBE labels should be expanded, to guarantee the impact of the programme.

Electronic equipment have large potential for efficiency improvements, as is shown by the current standby energy consumption and by the impressive reductions in energy demands of portable equipements (to save batter life); these devices provide high levels of service and can serve as a reference point for improvement potential in other electronic devices.

PBE should also be expanded to cover UPS systems and power supplies, as some of these systems have large parasitic energy consumption.

MEASUREMENT AND MONITORING

There is currently a large, nationwide effort aimed at the development of smart metering systems. Alongside the flexible peak hours for electricity charging, there is a large potential for improving efficiency and reducing costs through monitoring of buildings. Smart metering and smart grid programmes should guarantee benefits to the end-users. This includes access to the information produced, easy to use technologies for display of consumption data and technological development of demand-side response systems to reduce energy peaks.

DATA CENTRES

The energy consumption of data centres is rising fast. As they are often "mission critical" technologies, designs are generally highly conservative and miss opportunities for energy saving. A research project should create benchmarks for energy efficiency in data centres, and study the principle methodologies for consumption reduction and improved efficiency of systems.

DISTRIBUTED GENERATION

Market adoption of distributed generation technologies, especially PV systems, is currently slow, and should be supported.

Firstly, financial models should be proposed for the use of PV systems in social housing, funded by the utility companies. In one such model, the occupants would have the right to use all the energy generated by the system, but would have to buy any additional energy at standard market rates – the utilities would not be obliged to sell energy at the "social tariff". This could be implemented in the MCMV programme, with installation of systems of 1.0 – 1.5 kWp per dwelling.

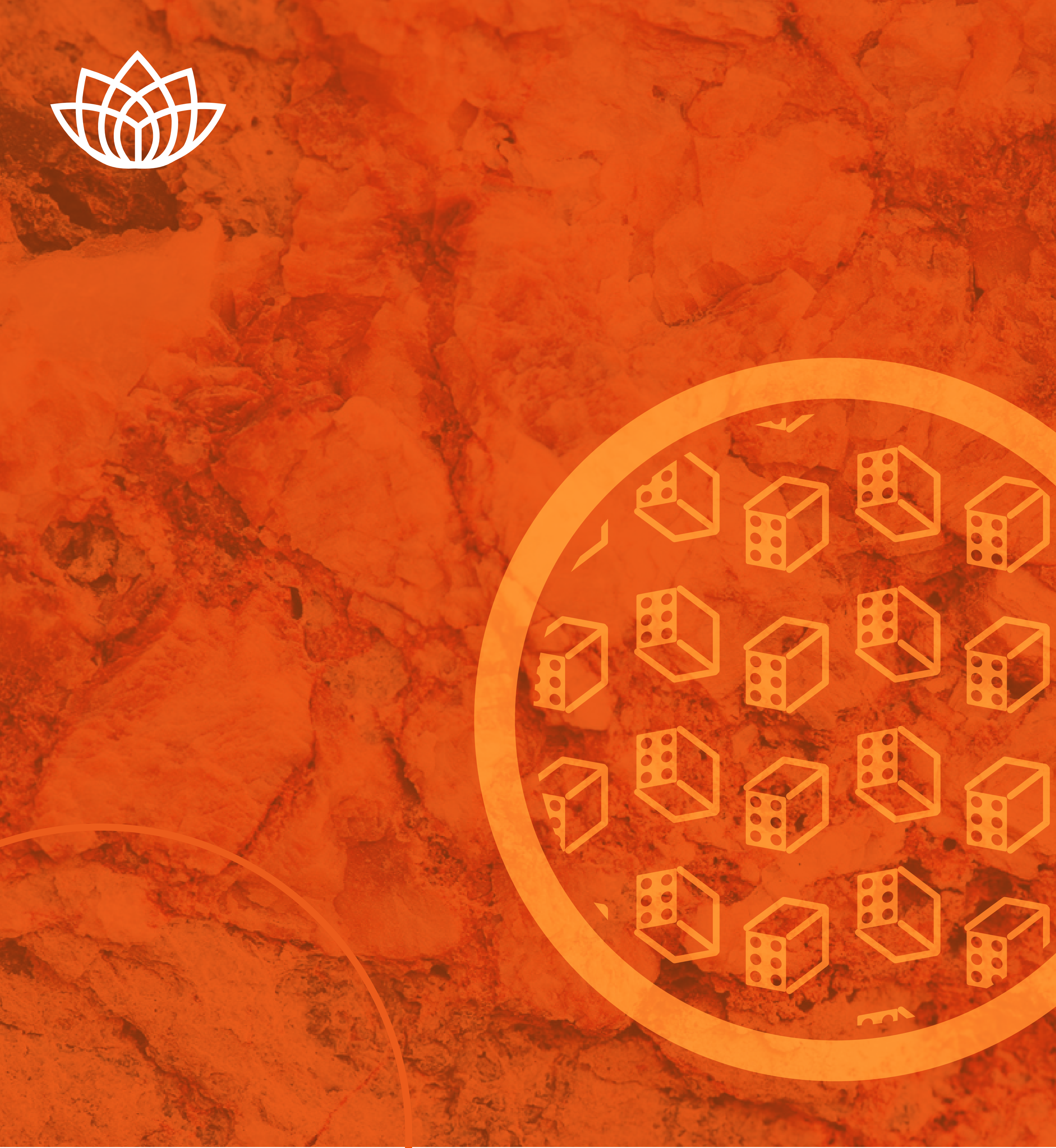
Current taxation requirements charge ICMS (a municipal tax) on the energy bought and sold by microgenerators, which significantly increases the cost of PV systems, increasing the payback time and often making them infeasible. Tax exemptions should be given for small systems.

Policy assessment matrix

	Institutional planning and management actions	Impact
1	Financial support models with a reduction in taxes for energy efficiency.	High
2	Utilitiies to facilitate access to consumption and demand data.	High
3	National energy efficiency agency, with an integrated energy policy in operation and materials.	High
4	Strengthening the *PBE Edifica* Program with: implementation of processes to make it compulsory in state and municipal government buildings; training and awareness-raising programs; and support tools for reducing set-up costs.	High
5	Creating an operational energy performance certification infrastructure, including: energy consumption benchmarks and Transparency Law models for adoption by relevant municipalities.	High
6	Adapting *PBE Edifica* for creating a low cost asset rating for existing buildings.	Medium
7	Research and development for supporting the creation of technical benchmarks for the sector, including benchmark models for stock and future climate years.	Medium
8	Integration of thermal comfort, energy efficiency and climate adaptation specifications in the *MCMV* Program.	Medium
9	Facilitating building retrofits, provided they reach certain levels of energy efficiency.	Medium
10	Program for the construction of exemplary buildings, with publication of consumption.	Low

	Awareness-raising and professional training actions	Impact
11	Training for facilities professionals, project architects, consultants, commissioning agents and energy auditors.	High
12	Improvement in university syllabuses with regard to energy efficiency.	High
13	Media campaign for sustainable and efficient construction tools.	Medium
14	Strengthening institutions and technical associations.	Low

	Technological actions	Impact
15	Increase the breadth and effectiveness of the efficiency assessment of air-conditioning systems in the *PBE* in the following ways: • Increase the minimum energy efficiency levels in air-conditioning systems; • Start to use SEER for evaluating the efficiency of air-conditioning systems; • Implement minimum standards and labeling on chillers that consider air and water condensation.	High
16	Expand *PBE* to cover other electronic equipment, especially no-break and energy stabilization systems. Review minimum *PBE* requirements for equipment for aligning with international standards.	High
17	Encourage the use of highly efficient ceiling fans as a thermal comfort measure.	Medium
18	Support the development of leading edge technology for reducing consumption in buildings, with a focus on: solar cooling, heat pumps for heating water and metering and control systems.	Medium
19	Publication of performance standards and labeling on cold surfaces.	Medium
20	Encouragement for the production of better performance windows and frames.	Medium
21	Take better advantage of the purchasing power of the *MCMV* and the program for introducing solar heating systems in the following ways: • Measure, check and evaluate the *SAS* in *MCMV*; • Use the *SAS* in *MCMV* to train and encourage an *SAS* installation and maintenance industry; • Support the training and the development of better interfaces between *SAS* and the users.	Medium
22	Expand the *ICMS* exemption to include micro-generators.	Medium
23	Require an assessment of the quality of lighting for supporting programs for increasing lighting efficiency.	Low
24	Create an integrated energy and water policy for combatting waste in both when pumping water.	Low
25	Develop policies for smart grids for maximizing benefits for building users.	Low
26	Publish energy performance benchmarks in datacenters.	Low
27	Use photovoltaic systems in the *MCMV* Program to substitute the social electricity tariff.	Low



PART III

MATERIALS

1. Introduction

It is widely recognized that the construction industry uses more than half the natural resources extracted from the planet in producing and maintaining the constructed environment. The expected growth in the world population and social demand for a good-quality constructed environment for everybody implies a worsening of environmental problems.

However, the consumption of natural resources with the extraction of materials is just the beginning of the issue, which extends throughout the life cycle of the products used in the sector. After extraction, raw materials are industrially processed, which requires energy and implies the emission of greenhouse and other gases. The mass transportation of materials and construction waste, and maintenance and demolition have a substantial environmental impact.

The loss of materials in the transportation, selling and construction phases worsens environmental impacts and the costs and volume of waste produced. These losses are aggravated by a lack of modular coordination of the projects and components, by the low levels of industrialization and by management deficiencies in the whole process. A significant part of the waste originating from construction, maintenance and demolition is disposed of in the urban garbage system or in illegal landfill sites, thus generating costs for society and aggravating environmental problems. It is still an exception for this waste to be recycled.

Deficient and poorly detailed projects that do not select the materials and components that are most appropriate for the specific situation not only unnecessarily increase the consumption of materials used in construction, but have an impact that lasts for the whole of the life cycle of the product. The selection of materials may affect the quality of the air inside buildings and imply the greater consumption of energy used for conditioning and of water during the long use phase. Deficiencies when planning the service life of buildings and infrastructure exacerbate the need for maintenance and demand the early replacement of the construction, thus cyclically renewing environmental impacts and increasing waste generation. Poor durability, which increases environmental impact, also reduces productivity and removes scarce economic resources from being used for expanding the constructed environment.

The informality that affects many sectors of the production chain implies low quality materials and poor service, which worsens environmental problems, creates social problems with regard to worker rights and leads to tax evasion. Moreover, the informal sector is not affected by public policies for cleaner production, a fact that may even benefit it if such policies mean an increase in costs for the formal sector.

The selection of the most suitable materials and components for each project is a complex activity since it implies assessing the aspects that include market variables (cost, the informality of the production chain) and technical aspects that require mechanical and chemical knowledge and knowledge of physics (mechanical properties, conductivity, thermal capacity, durability in the application desired, health at work and waste management) and environmental aspects (extraction and beneficiation processes, service life in the application, expected losses in the process, etc.).

Given the complexity involved in selecting the best combination of materials for each project, the topic has been largely neglected and what has prevailed is the replication of standard solutions, regardless of the environment and even of the target-public, with the selection of suppliers being based purely on price. This practice not only eliminates the possibility of mitigating environmental impacts, but also makes it difficult to introduce innovative solutions, which negatively affects productivity and reduces the social value of the construction in general and of the engineering and architecture in particular. Even cost considerations during the use phase have been neglected in most of the projects.

Reliable information and tools that are suitable for day-to-day activities and that allow the professional to make an objective assessment of many of these aspects are wanting in the Brazilian market. Market professionals from the whole of the production chain are also lacking in adequate technical knowledge.

Based on the context presented, the objective of this work is to indicate priority themes for public policies aimed at increasing the sustainability of construction. These proposals take as their basis an analysis of the current context in the country. This involved research with members of the production chain, looking at the experience of public policies in other countries and also examining emerging concepts in world literature.

The text begins with a diagnosis of the building materials and components' sector on a national scale and from the viewpoint of the life cycle of a building. It then provides a summary of important international experiences and the trends detected in the literature that have the potential for launching solutions for the problems encountered in the Brazilian diagnosis. Finally, we present suggestions for the public policies that are considered to be a priority and an assessment of the difficulties it is expected to encounter in introducing them.

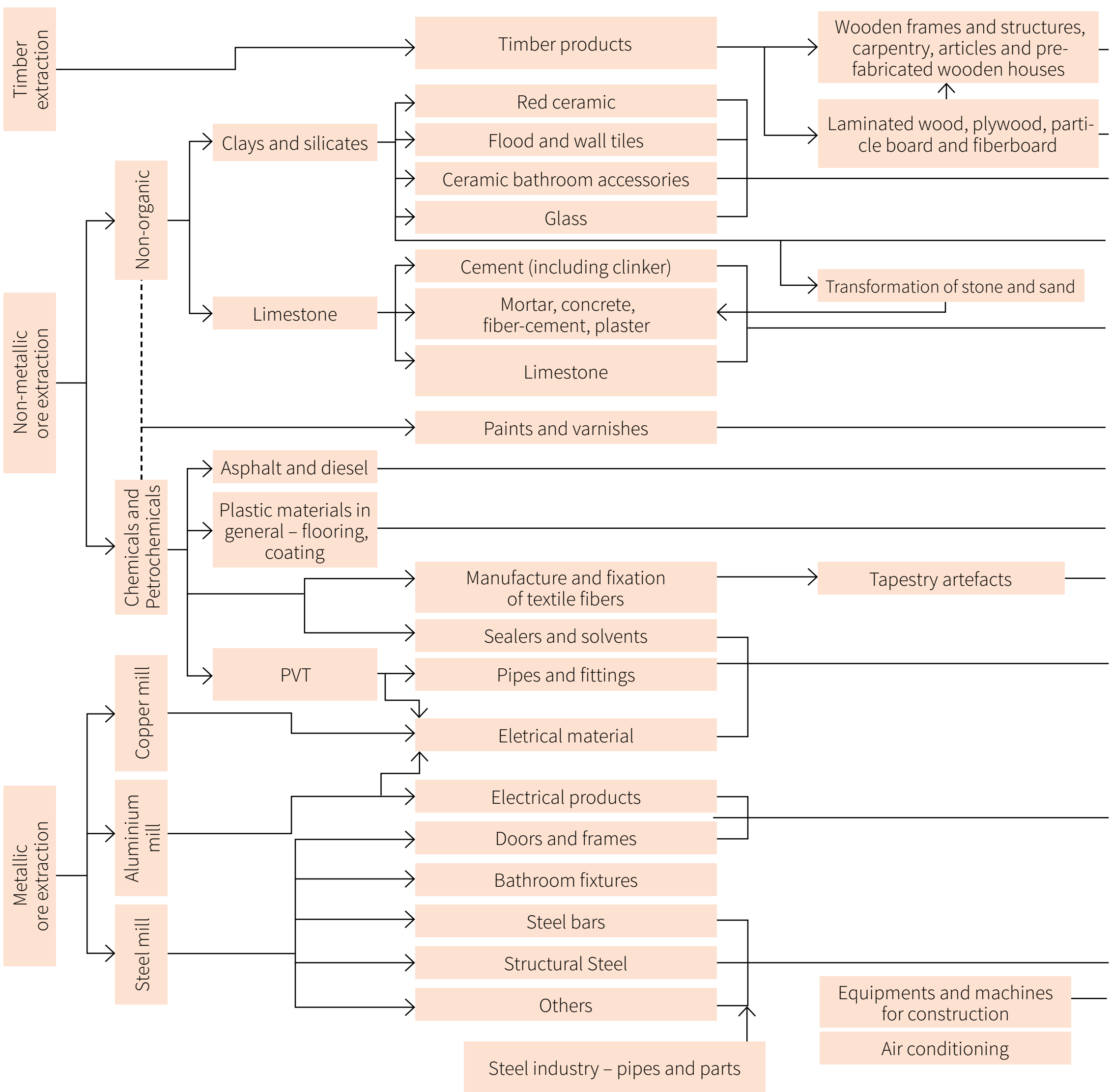
2. Diagnosis of the building materials sector

The building materials and components chain

Despite consuming a good part of the natural resources, the building materials industry represented just 1.5% of Brazil's GDP in 2013, with an added value of R$ 61 billion (*ABRAMAT*; FGV Projects, 2014). Construction products, therefore, are predominantly of low value. It is expected that the construction sector in Brazil will double in size between 2009 and 2022 (FGV PROJECTS, LCA CONSULTANCY, 2010). If current sector practices are maintained, this growth is likely to exacerbate environmental and social problems related to building materials. Innovation, therefore, is a necessity.

The building materials and components' sector involves everything from extraction activities (sand, gravel and native wood) to parts of the chemical industry. But wood, cement materials (which include sand and gravel), heavy clay and steel are responsible for most of the construction products. Some sectors, like cement and ceramics, are dedicated exclusively to construction. Others, like steel, plastic and wood allocate a variable part of their products to construction. Sectors that also serve other markets tend to be less sensitive to policies aimed exclusively at sustainable construction.

FIGURE 21 – BUILDING MATERIALS CHAIN



SOURCE: ABRAMAT (2007)

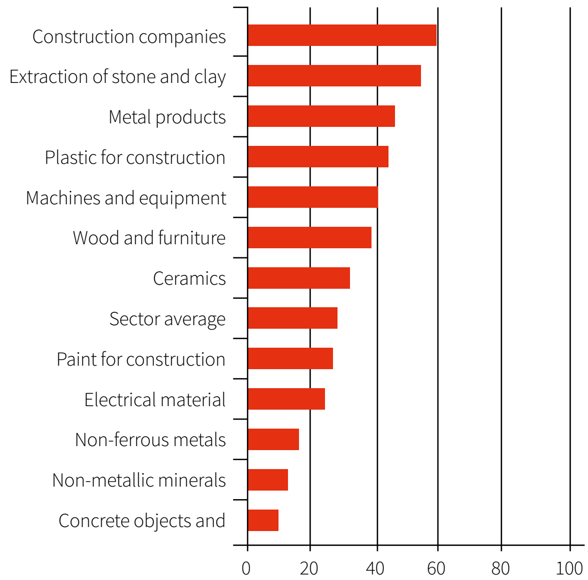
The production chain of some materials and components is made up predominantly of small companies, frequently with large degrees of informality. At the other extreme are chains that comprise a small number of large manufacturers. Between these two extremes there are many sectors containing both large and small companies. Public policies that are appropriate for large companies are not necessarily appropriate for small and medium-size companies.

In 2013 direct sales to construction companies represented 24% of the revenues of the materials industry (*ABRAMAT*; FGV PROJECTS, 2014). Some 60% is sold to retailers and wholesalers, with a predominant part destined for small consumers, including self-managed construction and maintenance and informal construction. In some sectors in which the life cycle is shorter, like paint, this portion is even bigger. Retailers need to be committed to efforts for more sustainable construction. So the introduction of public policies aimed at constructors has an important, albeit limited, effect: to a large extent, "retailer" consumers are not trained to buy in a technical way and they will find it difficult when it comes to knowing how to choose alternatives that have less impact (if they exist in the future). These consumers are also little influenced by municipal regulations regarding construction practices or environmental seals. Success in this market starts with the creation of conditions for fully substituting products that have the greatest impact by others that are more efficient, as happened with the introduction of 6.5L toilets, a strategy that combined combatting informality (via *PBQP-H*) and standardization, in such a way as to reach all consumers in the materials industry, whether large construction companies or small consumers. It is essential that policies are also developed that allow for the environmental impact in self-managed construction to be mitigated.

Informality in the materials production chain

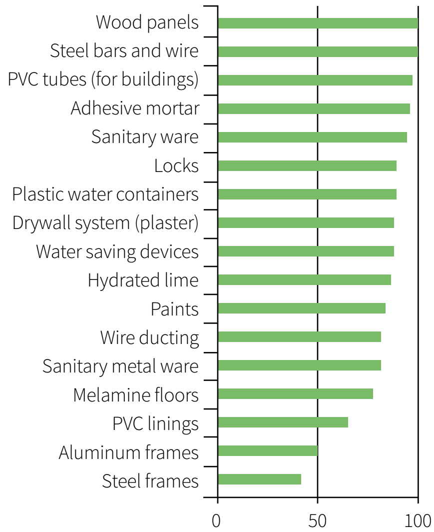
The informal economy has usually been defined as economic activity that is not declared to government agencies, especially to the tax authorities, but also to the environmental authorities. It represents a significant percentage – often greater than 70% – of the economy of developing countries. In Brazil, based on the experience of the Brazilian Housing Quality and Productivity Program (*PBQP-H*) a new dimension was added to informality: deliberate technical non-compliance, defined as the deliberate placing of products in the market that do not meet the required technical standards. Figures 22 and 23 show the informality indicators in the materials and components' chain. The case of native wood from the Amazon, which is not registered in the statistics mentioned, highlights the environmental dimension of informality.

FIGURE 22 – INFORMALITY IN THE BRAZILIAN CONSTRUCTION PRODUCTION CHAIN IN 2006



SOURCE: FGV PROJECTS (2006)

FIGURE 23 - INFORMALITY (COMPLIANCE WITH TECHNICAL STANDARDS) MEASURED BY THE *PBQP-H*



SOURCE: BRASIL (2014)[1]

Informality is an unfair competitive strategy aimed at easily and quickly gaining market share or expanding profit margins, without needing to invest in productivity or quality. However, in some situations it might be the result of bureaucratic impasses and in markets dominated by informal companies it may be the only short-term survival strategy. The poor quality of the materials produced means that products need to be replaced [more frequently], which increases the environmental impact and leads to losses for consumers. The informal will always be more cost-competitive, but the social costs are high, ranging from a lack of quality in the end products, which are commonly not in line with the minimum technical standard requirements, to a reduction in the capacity of the state to invest in infrastructure, due to the reduction in the amount of tax collected. In sectors in which informality predominates, market prices end up depressed, which inhibits the introduction of innovation, including innovation that has a lower environmental impact. Such is the case with wall cladding masonry, particularly in the high-rise buildings that dominate markets that have very different climates.

Informal companies do not respond to public policies. Moreover, regulations that increase costs for formal companies, whether taxes or costs of an environmental nature, tend to increase the competitive advantages of informal organizations. In this scenario, what is most recommended is incentives for the formal sector. Combatting informality in all its dimensions is a condition for making the materials' chain more sustainable.

PBQP-H has developed a single strategy on an international scale for combatting deliberate non-compliance in the materials industry. Quality improvements in the materials industry avoid repeated impacts because of performance failure and is a condition for promoting sustainability. *PBQP-H,* therefore, needs to be expanded. In the absence of any other efficient methodology, small and medium-size companies need to he helped to participate in the *PBQP-H's* Sector Quality Programs (*PSQs*), since these programs would have enormous environmental and cost impacts.

[1] Available at: <http://pbqp-h.cidades.gov.br/resultados_projetos.php>. Accessed on: Oct 27, 2014.

The industrial chains in which there is little informality, including those organized in the *PBQP-H*, have more potential for introducing strategies for promoting sustainability. An effective strategy in some production chains is the progressive introduction of environmental requirements in sector programs that come under the umbrella of the *PBQP-H*, which is a trend we are already seeing in some sector materials programs.

As the retail trade is the main sales channels for materials we have to conclude that informality runs through this link in the chain. So it will be impossible to combat informality effectively without actions directed at this sector. Mechanisms like the electronic invoice, combined with the standardization of product codes and units of sale and the obligatory registration of the manufacturer's *CNPJ* [*corporate taxpayer's identity number*] on the invoice are just some of the tools for acting over the medium- term. In the short-term, however, the sector needs to be mobilized. The *BNDES* card and public building works (My House My Life and the PAC) programs are important tools for connecting the state's purchasing power and the retail trade.

The *CBCS* currently offers an on-line tool called "6 steps for selecting materials and suppliers" (available at: **<http://www.cbcs.org.br/selecaoem6passos/>**), in which it is possible to consult the formality of the manufacturer of the required material. This is a tool, which despite being little publicized, has the potential to help combat informality.

Informality in the Brazilian construction chain and within the building materials production chain, is certainly one of the most important contributing factors to the lack of sustainability in Brazilian construction. Combatting informality is a priority.

Environmental impacts in the production phase

The materials' industry consumes approximately 50% of the extracted natural resources. As a consequence, the sector is obliged to use only materials that are found in abundance and are low cost. So it is unlikely that materials will appear that are radically different from those used today, which are based on silicon, aluminum, iron and calcium, the most abundant chemical species on earth. Given the demand, which is likely to increase significantly over the next few years, none of the main materials currently used will be able to be substituted. Unlike other sectors, in the building materials area, mitigation of the environmental impact is going to depend on improving existing products. In this sense, basing sustainable construction on substituting one material for another may reduce the environmental impact of a particular construction job, but will hardly reduce the overall impact of the sector.

An estimate based on data that is available in the second Brazilian Greenhouse Gas Inventory reveals that CO_2 emissions in Brazil during the production of materials are more important than the emissions that are associated with these same materials when they are being used in buildings (AGOPYAN; JOHN, 2009). This is due to the high emission levels of some materials, to the clean energy matrix and to low energy consumption, particularly thermal energy, when buildings are being used. In Brazil, therefore, greenhouse gas mitigation in the construction phase has more to do with the materials chain and less to do with energy consumption throughout the life cycle, although the latter has been deteriorating in recent years.

Construction requires between 4 and 7 tons of material per inhabitant per year (AGOPYAN; JOHN, 2009). The scale of resource use in the production of materials, given at least in part by the planetary and human size of the constructed environment, makes environmental impact large, even when we consider products with the lowest impact. Dematerialization and recycling are important strategies for reducing environmental impact. Some materials' industries already use a large amount of waste. Cement works, for example, recycle large amounts of pig iron and fly ash waste. Metal industries recycle their own waste.

Despite the progress of the institutional framework in the construction waste area, the recycling of construction and demolition waste on a large scale, except for metals, is going to depend on incentive policies for production and consumption. Dematerialization, which can be understood as adopting light construction systems or reusing components at the end of the service life of the construction, is still a strategy that is little known by society, which is going to depend on more radical innovation in construction systems, on fighting informality and on more incentives for innovation and industrialization.

Part of the heavy consumption of materials and waste generation is associated with the loss of materials on construction sites (SOUZA *et al.*, 1998). Studies carried out in the 1990s showed that losses depend on management of the job site and of the project, but they are also influenced by the materials themselves. It was particularly clear that losses reduce with the increase in the degree of industrialization of the solution: losses of cement and aggregate that are used for producing concrete on the job site are much greater than the losses that occur when using ready-mixed concrete. Masonry components break at different stages of handling. The adoption of modular coordination could avoid the need for cuts and adjustments in the construction work since these generate a lot of waste and reduce productivity in buildings. At the extreme of industrialization are assembly-based systems, in which the possible losses are very low. Policies that encourage the use of industrialized solutions, with guaranteed performance and durability, can reduce environmental impact by reducing losses, with the added bonus of increasing productivity, thus helping increase *per capita* income in the country. Fiscal policy has overly-delayed the industrialization of Brazilian construction, reduced sector productivity and increased losses and the rate of defects, and this leads to significant environmental impact. Such is the case with ready-mixed concrete, which uses technology that implies an increase in the environmental impact of concrete (through an increase in the consumption of cement) in order to reduce taxation. According to *Abramat*, currently even frames are being produced on job sites, leading to an enormous failure rate and waste of materials.

In comparison, with increasing numbers of international standards, concern with the use of toxic substances in Brazil is still in its early stages. The discussion that has been dragging on for some time has to do with the opportunity to ban asbestos, for which there are already substitutes in the Brazilian market. After 20 years of discussions there is still no fundamental plan, in other words, time goals that guide the sector in the transition away from these substances. The most notable example is the banning of products based on pentachlorophenol by *Anvisa* (ANVISA, 2007) as from 2007. This is a topic that takes a long time to mature and with which only the international companies that operate in Brazil are already familiar. The implementation of the Chemical Products Safety Information Sheet (*FISPQ*), based on the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) is certainly a first step in this discussion.

Environmental management in the manufacture of materials

Generally speaking, major companies adopt ISO 14000 standard environmental management practices ad present their social and environmental responsibility reports. In sectors like cement and steel, a significant proportion of the companies produce a greenhouse gas inventory; some, like the cement sector, are integrated in a global effort, with direct emission data (average values) that are audited and publicly disclosed in their reports. Some companies take part in voluntary programs, while others still do not comply with the minimum aspects of environmental management and even operate without an environmental license.

However, it is not the practice of sector companies, as it is not in any other Brazilian corporate sector, to disclose quantitative data regarding the environmental impacts of their products. This is the result of the way Brazil has been dragging its heels with regard to using the Life Cycle Analysis (*LCA*) tool. Nevertheless, it has to be recorded that given the complexity of the tool, the traditional, complete *LCA* has not been feasible as an environmental management tool, even for large companies. But the introduction of the tool in an effective way depends on the capacity of companies to manage and measure their environmental impact.

Various companies report that they supply environmental information to their customers that need it for green building certification purposes. However, these "product environmental declarations" are not, as a rule, checked by a third party, do not cover the life cycle of the product and are limited to aspects like waste content and the emission of volatile organic compounds (VOC), which are also requested for inorganic and metallic products, whose process guarantees that they do not contain organic substances.

What we observe, therefore, is the existence of different levels of familiarity and engagement with the management of environmental impact among companies and production chains, a factor that needs to be considered when it comes to formulating public policies. The consolidation of these tools is a condition for mitigating environmental impact. These tools are certainly incompatible with informality.

Impacts in the use phase

Despite the well-known importance of the impact of materials in the production phase, environmental impact in the use phase can also be large.

Some materials, like water-based paint (UEMOTO; AGOPYAN, 2006), wood-board and systems that use adhesives have the capacity for emitting volatile organic compounds (VOC). Depending on the nature of the volatile substances, the amount released and the concentration in the environment (which depends on ventilation) the internal environment of the building may be contaminated and operatives exposed to situations that are a risk to their health. In Brazil this subject is still in its early stages, but has already engaged the paint industry throughthe Brazilian Association of Paint Manufacturers (*Abrafati*), which is an integral part of the international effort of paint and wood-board manufacturers, which have already come up with a specific technical standard. This subject is likely to gain in increasing importance due, among other factors, to the performance standard for buildings, which significantly increases the tight-fitting qualities of windows, which is also for controlling noise, and to the proliferation of split-type air-conditioning equipment, which does not ventilate the environment. We see that both academia and the market have little understanding of this matter. Encouragement is certainly needed for developing mechanical systems that guarantee both ventilation and acoustic insulation.

Another possible impact in the use phase comes from the leaching of hazardous chemicals from materials exposed to water, especially on roofs, in wall cladding systems, in various construction works and in foundations. These chemicals contaminate the soil and the water table. Environmental contamination has been reported on an international scale with the use of biocides, particularly in wood and paint (TOGERO, 2004), but also when waste is included in building materials. In this aspect Brazilian experience is very small and the country has no specific technical standards relating to this topic; the use of standards aimed at regulating the disposal of waste is recognized as being totally inadequate (JOHN, 2000). Of particular concern is the tendency in some states in Brazil to create specific regulations for each family of waste. This is an emerging theme, with considerable potential for opening up a market for the use of waste as raw material, which needs to be the subject of research and the drawing up of standards.

The durability of materials controls the impact of construction products. The longer the service life of the construction, the lower the total economic and environmental costs, because there are fewer maintenance activities (which also generate waste) and less material needs to be replaced. Planning service life is an exception in Brazil, even in infrastructure construction work. The most popular green building environmental certificates in Brazil do not include a reference to durability (HAAPIO; VIITANIEMI, 2008). Nevertheless, Performance Standard, NBR 15575/2013 (Buildings for Housing – Performance) established for the first time the need to condition the project to a minimum service life, which is great social and environmental progress.

Durability, however, is not an intrinsic characteristic of each material, a factor that makes it difficult to incorporate this variable into projects. It depends basically on the interaction of the characteristics of the material with the weather conditions and on the project details to which the material will be exposed. So problems relating to the durability and service life of a given material vary significantly according to the region or even according to the project details. Application of this tool comes up against the lack of geo-referenced models and information regarding the relevant environmental parameters that enable the life of products in different situations to be estimated. Only reinforced concrete has had a model like the one mentioned for more than twenty years (HELENE, 1986), but elements of Brazilian engineering are still resisting incorporating it into a technical standard.

According to *Abramat*, the *PBQP-H* has a group that is organizing information to characterize construction subsystems in order to generate a virtual catalogue with performance references for the *MCMV* Program. Inconsistencies appeared in the survey that was undertaken by the group, because the information supplied by companies and manufacturers was not always evaluated using the same methodology, which makes it impossible to carry out a comparison. This fact emphasizes the need to create single methodologies for measuring impacts in the life cycle.

From the viewpoint of the materials industry, there is a lack of human resources training and a laboratory structure is needed that will enable companies to find out the service life of their products, particularly the most innovative ones, under different situations.

Impacts in the post-use phase

The flow of materials throughout the life cycle generates waste, from the extraction and manufacturing process through carrying out the construction work, to the use/maintenance and demolition/deconstruction phases of the building.

It is estimated that much of the material returns to nature as production material waste or waste resulting from unsuitable construction practices within the first year after its extraction (MATHEWS *et al*., 2000). At the end of the service life approximately 5kg of waste is generated for each kilo of material used (JOHN, 2000). A clear example of how this occurs is the production of aluminum, in which 5kg of the raw material, bauxite, are extracted to produce 1kg of the product; in other words, a large part of the waste generated occurs even before the product is ever used. In the case of aluminum there is also the aggravating factor that the residue generated is a major environmental contaminant, called red mud. Copper, in its turn, generates 99g of mineral waste for every kilo of material made ready for use (GARDNER, 1998).

If we consider just construction waste, there are estimates that 500kg per inhabitant/year used to be generated in Brazil (PINTO, 1999). More recent data indicate that an average size city in up-state São Paulo (in this case, São Carlos, with its 270,000 inhabitants generating 600 tons/day of waste) is currently generating a little over 800kg per inhabitant/year of waste, which shows that the figures have increased significantly over the last few years and may be much bigger in large metropolises, where the pace of growth in the construction sector has been huge.

Conama Resolution 307/2002, which establishes guidelines for the management of construction waste, instituted the separation of waste by class and obliged municipalities to have policies for the management of this waste. This, however, did not happen in a satisfactory manner after the period determined in the document and a large amount of construction and demolition waste is being disposed of in irregular locations, while regular landfill sites are being rapidly exhausted, obliging increasingly large amounts of spending on areas set aside for this purpose.

Therefore, the management of construction and demolition waste in Brazil, despite many documents and studies, still leaves a lot to be desired when compared with international practices. Even though some private companies have come into the business, the amount of Class A waste (masonry, plaster and concrete) that is actually recycled is still very little.

The same resolution commits a big error in classifying all wood products as Class B waste (easy to recycle), since part of this waste is treated wood. In the construction phase the main biocide currently used is chromated copper arsenate (CCA). But activities that involve demolition can come across products containing pentachlorophenol, which is highly damaging to health; sleepers, which are traditionally treated with this substance, have even been used for making tables. This industrialized wood also contains resins, adhesives and paint. Waste containing these materials needs to be handled in a special way. It is recommended that the resolution should be updated as far as concerns the aspect highlighted above. There is also a complete absence of policies aimed at the growing economic activities of demolition companies and the management of construction waste.

The research entitled "A study for promoting sustainable civil construction by national policy: a consultation of sector professionals", which was presented in Chapter 2 of this document, shows that a lack of information and of trained professionals are the main reasons indicated as a barrier to the recycling of construction waste. This is extremely relevant, since it shows a generalized lack of databases dealing with the life cycle of materials, which is prejudicial to the sustainability of the chain. The low value attributed to waste, labor costs and the distance to landfill sites or recycling centers, all of which could be cost-linked obstacles, were mentioned much less frequently than the lack of information and qualifications.

Generally speaking, product users are lacking in clear instructions on the correct handling of products whose waste is potentially not inert (Class D), which includes not only wood products, but also paint, lubricants, adhesives, cloth, etc. This deficiency could be easily overcome by adopting policies that disseminate complete Chemical Products Safety

Information Sheets (*FISPQ*) (CBCS, 2012), according to NR 26, which was recently revised according to the GHS world standard; these must now include instructions for managing waste and those relating to worker health. What we see, however, is that few companies make such sheets available, and many of them, even when supplied by companies that publicly acknowledge their environmental commitment, are incomplete. With regard to waste, for example, a popular recommendation is "to dispose of waste according to current legislation".

There is, also, little experience in building deconstruction or disassembly in Brazil. Most buildings are demolished by destructive methods that mix the waste and considerably reduce its recyclability and reusability. The exception to this was the deconstruction project managed by GM, which was planned by the *IPT*; all the waste that was generated was successfully re-used.

The lack of a systemic view and of an impact assessment throughout the life cycle have affected the effectiveness of some public policies. The banning of incandescent lamps, the market for which is likely to be taken over mainly by fluorescent lamps, is an example of this. The decision was taken by inter-ministerial ordnance (MME, 2010) and did not involve the Ministry of the Environment. Fluorescent lamps contain mercury. The market was offered to the manufacturers without any concern for establishing maximum mercury content (JUNIOR; WINDMÖLLER, 2008). The Conama process with regard to managing this waste was started in 2002 and public consultation is still being concluded[2]. An aggravating factor is that in most actual use situations, the working life of compact fluorescent lamps will be much less than the nominal figure shown on the packaging. This has been used to show that the measure has a negative cost for consumers. It just so happens that the working life of compact fluorescent lamps depends on the number of on-off cycles (DA SILVA *et al.*, 2010). Used in typical room situations where they remain switched on for little periods of time their working life will be the equivalent of incandescent lamps. This not only multiplies waste generation but also significantly increases the life cycle cost, thus being prejudicial to users.

The above example is a typical case in which a policy of an environmental nature (energy) was adopted without a life cycle assessment being carried out or without engaging different agents, including state bodies, academia and society. An opportunity was lost to demand any counterparts for society from the few companies that benefited, not only in terms of improvements in environmental performance, but also in the generation of employment in the country. The legal and institutional framework was also not adequately prepared and society has been left exposed to unforeseen environmental impacts. In order to improve the effectiveness of public policies aimed at sustainability, their preparation process needs to be qualified.

The specification of more sustainable materials

Various sectors of the Brazilian materials industry generate products with environmental impacts that are less than what is typical globally. Such is the case with the cement, steel and planted forest industries. Even in the production chains that are most behind in the environmental agenda, supply companies can be found whose environmental impact is very low. Generally speaking, options for reducing the environmental impact of construction

[2] Available at: <http://www.mma.gov.br/port/conama/processo.cfm?processo=02000.001522/2001-43>. Accessed on: 10/30/2014.

exist, but there are no communication or knowledge tools that allow society to increase the benefits of this supply.

The reality is that the part of the market that is mobilized to mitigate environmental impacts is still minute. For many chains in the construction materials area that depend on the retail trade it is even smaller.

When there is an environmental concern, decisions are normally guided by a list of "green" materials that is based on one-dimensional criteria, like the level of volatile organic compounds, waste level, energy used (in the production process), or is present on the check lists of green building seals, which are most often developed for other realities. The use of one-dimensional criteria, even though conceptually correct, may lead to decisions that increase environmental impacts. Such is the case with the incentive given for the use of recycled materials (including construction waste, plastic, and tire rubber) as aggregate in the production of concrete. This often leads to a large increase in the consumption of cement in the concrete (DAMINELI, 2013), thus increasing the environmental impact and cost.

Despite the existence of a supplier selection tool developed by *CBCS* that helps reduce informality, called "6 steps to the selection of materials and suppliers", the emphasis is still on selecting the best product, ignoring the fact that environmental impact differences between suppliers of the same product may be much greater than between competing solutions. Comparisons are frequently carried out *en masse* (J/kg) and not by unit of equivalent function, which leads to enormous distortions. Aspects that define the environmental impact throughout the life cycle, like service life, maintenance needs and dismantling and reuse possibilities are rarely considered. The tool also faces limitations because of a lack of public disclosure on the Internet in most of the states in Brazil of current environmental licenses, indexed by *CNPJ*.

The life cycle assessment tool, the most appropriate tool for taking decisions that consider environmental aspects, is still little known and even less well-understood by Brazilian professionals. Only in 2010 was the Brazilian Life cycle Assessment Program (*PBACV*) created, through *Conmetro* Resolution 004/2010. As a consequence, those who know the tool do not have national data available for using it. In addition to the results of life cycle inventories, the use of the *LCA* depends on information about the service life of products in different markets. The traditional strategy for introducing *LCA* in countries starts with the construction of databases that contain a detailed inventory for each input. The current hypothesis is that if the "technological routes" of production of a product are maintained, then the impact is not going to vary. But empirical data from the Brazilian market, including initial data of the project for introducing the modular *LCA* in the concrete block sector[3], show that the differences between manufacturers are more important than those found between competing products that have the same function. The construction of these databases also usually takes decades.

In the Brazilian case the research presented in the chapter entitled Consultation of Sector Professionals in this document showed that most materials are selected in the project and budgeting phases (more than 70%). But the high rate of selection in the construction phase on the job site (approximately 30%) shows that the construction company frequently alters

[3] The ACV-m project for concrete blocks was funded by the Brazilian Portland Cement Association (*ABCP*) and the Brazilian Association of Concrete Blocks (BlocoBrasil) and developed by *CBCS* and the University of São Paulo (available at: <www.acv.net.br>).

the materials selected in the project phase during the construction phase. In addition to the difficulties that this causes in carrying out the work and the waste that occurs due to this act of "designing on the job site", the main factor in this information is that the difficulty in selecting materials does not appear to be linked to the lack of a project or planning, but to a lack of knowledge for preparing specifications; if the materials are changed on the construction site it is because there was some error or problem during specification preparation in the project phase.

The research also shows that the criterion used for selecting the materials most widely used is cost, which explains why selection occurs mainly in the budgeting phase. On the other hand, manufacturer-based selection by list of sustainable materials using the *LCA*, or the amount of direct CO_2 emitted, were each mentioned by fewer than 20% of those interviewed, showing that a lack of data for selecting based on sustainability criteria is a fact that jeopardizes the project sector. Because of this lack of data, selection is normally based on few criteria or on just one criterion and in a very simplified way, which leads to problems.

The lack of technical knowledge of the project design team was the option most mentioned as a difficulty for selecting materials, which in its turn has its origin in the lack of available data that was pointed out. If this fact is added to the replies that point to a lack of information about *LCA,* performance and the manufacturer, the great difficulty experienced in selecting materials based on sustainability criteria is linked to a lack of data about various aspects.

However, research shows that the sector already understands what it is important to know when selecting materials, because the most frequently mentioned topic was the relationship between a kilo of material / functional unit / durability / impact. These indices are clearly linked to *LCA* concepts, which proves that the lack of knowledge of the team depends much more on making data available than on any real lack of team knowledge. So the sector considers the *LCA*, therefore, to be the most useful tool for selecting materials. Concern with the formality of the supply companies, however, was mentioned very little, which is worrying, seeing that formality is one of the most important aspects of sustainability in construction and is closely linked to adhering to product compliance standards.

Abramat, *Sinduscon*-SP, *Secovi* and *Asbea*-SP are putting together a materials guide for dealing with the problem associated with product specification. A great need that has been detected is that of training in the sector for creating a 'specification' professional, a person who has mastered technical and product standards and sector information. The production chain is 'contaminated' by the traditional way of working, in which the project is completely sectorized. For there to be innovation, engineering and the project must take place at the same time.

Therefore, policies for sustainable construction need to face up to both a lack of human resources training and of relevant technical information.

3. International experience

Life cycle Assessment in construction

The ISO 14000 family of standards introduces environmental management to the corporate world on different scales. Certainly the most sophisticated tool for quantitatively assessing environmental impact is the Life Cycle Assessment (*LCA*), which is described in the ISO 14040 series of standards. *LCA* has established itself as the quantitative tool for the environmental management of products. Official public databases of inventories progressively appear, like the International Reference Life Cycle Data System (ILCD) of the European Union, which serves as inspiration for the Brazilian *PBACV*.

From the viewpoint of materials and components, what is important is the construction not only of general databases, but the possibility of comparing manufacturers, which becomes possible with product certification or labelling. Environmental labelling that is currently based on ISO 14020 standards, which are not LCA-based, has been abandoned in favor of "Product environmental declarations", known technically as Type III environmental labelling that was established by ISO 14025, including for construction. European regulation 305/2011 about the construction products market establishes product environmental declarations as the tools to be used for assessing environmental impact. Such declarations must cover the whole life cycle of the product.

In France we find perhaps the pioneering example so far of the application of the family of ISO 14000 standards to building materials. The *Plan National Santé Environnement* (*PNSE*) [National Environmental Health Plan], published in 2004, includes disclosure of the quantitative data of the environmental and health impacts of construction products. The *INIES* database was also established in 2004 and today has quantitative environmental and health data of a significant proportion of the construction products available. The database has an important characteristic in that it includes the expected service life of the product under benchmark conditions. Many of the data are still general, like the typical French wall plaster inventory, for example, but the number of product environmental declarations issued by companies is growing very rapidly.

The impulse for using these *LCA*-based declarations in construction has been based on a standardization effort that details and simplifies the application of the *LCA* in the construction industry. Two committees work in conjunction on this effort in the European Union: ISO/TC 59/SC 17, "Sustainability in buildings and civil engineering works" and CEN/TC 350, "Sustainability of construction works". An important standard that is currently being prepared is ISO CD 21930[4], "Sustainability in buildings and civil engineering works – Core rules for the environmental declaration of construction products and services used in any type of construction work", which establishes the methodology to be used for creating the product category rules that are essential for guaranteeing that the environmental declarations for Type III products based on ISO 14025 are compatible and comparable. In the international market we are already seeing the existence of various product category rules, including for concrete. Both ISO CD 21930 and EN 15804:2013 reduce the list of environmental impacts to be considered in construction in comparison with the one adopted in the ILCD and the complete *LCAs* in general.

[4] The corresponding standard in the European Union is EN *15804*:2012+A1:2013, *Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products.*

This is clearly a simplifying strategy given the practical problems faced, which are delaying the introduction of this tool by individual companies. In addition, EN 15804:2013 includes a series of indicators aimed at the intensity of the use of materials, water and energy, which are important items on the agenda of sustainable construction but are not usually included in traditional *LCAs*.

TABLE 9 – LIST OF ENVIRONMENTAL IMPACTS OF THE EUROPEAN UNION'S ILCD, EMPHASIZING THE IMPACTS INCLUDED IN ISO CD 21930 AND IN EN 15804:2013, AIMED AT CONSTRUCTION PRODUCTS

	Standard impacts of the ILCD / European Union	Standards for construction
1	Climate change	X
2	Destruction of the ozone layer	X
3	Human toxicity	
4	Breathable organic particles	
5	Ionizing radiation	
6	Photo-chemical formation of ozone (ground level)	X
7	Acidification of water and soil	X
8	Eutrophication of water and soil	X
10	Eco-toxicity	X
11	Land use	
12	Use of natural resources (minerals, fossil energy, renewables, water)*	X

*EN15804 includes 15 optional indicators for this item.

SOURCE: ILCD

Also with the idea of facilitating the market's use of *LCA* and Environmental Product Declarations we observe a tendency to integrate them with the Building Information Model (BIM), a new class of project tool.

So the tendency is to promote environmental product declarations in construction, using less complete versions of the *LCA*.

Sustainable construction plan of the European Union (EU)

The question of sustainable construction has been the object of important reflection on the part of the EU.

The European Union recently launched a task-force entitled "Sustainable industrial policy, construction and raw materials". The objective is to identify possible inefficiencies and other coordination issues linked to the main contributions of the construction sector to the EU strategy for 2020, which includes among other things long-term policies for industrial products, like building materials.

The main aspects for introducing the network of efforts are based on the following points:

1. Action plan for the sustainable competitiveness of the construction sector;
2. Regulations for the eco-design of industrial products and support services;
3. Waste as a resource for European industry;
4. Partnerships for innovation in raw materials within the EU.

The "Construction 2020 Action Plan" was organized in 2013 in two meetings that were held in the shape of forums and in a further two meetings for each of the five theme groups that were instituted. Initial results included initiating processes for adopting the first group of regulations for eco-design and energy labelling for industrial products. A review of Directive 2008/98/EC (that deals with waste) was also implemented, which resulted in a study called "Treating waste as a resource for the EU industry: analysis of various waste streams and the competitiveness of their client industries". As a result of this study a new process, which extends until 2015, will arrange for an assessment of the economic benefits of the use of industrial waste.

An important characteristic of the action of the European Union is the negotiation process, which involves representatives from the different countries as well as the association of industrial and professional sectors.

Regulated hazardous substances

The effect of ventilation and the release of volatile organic compounds and other particles on the quality of air in buildings and the banning of substances that are considered hazardous, like asbestos (particularly in the shape of thermal insulation) and lead-based paints, were forerunners in construction. Today this particular agenda is being led by the industry. In the case of paint the International Paint and Printing Ink Council (IPPIC) is already developing "Coatings Care", which is being progressively adopted in Brazil by *ABRAFATI*.

The current dynamic is for a much more in-depth control of hazardous substances. Internationally, in 2011 the Globally Harmonized System of Classification and the Labelling of Chemicals (GHS) (UNECE, 2011) was published and adopted by Brazil; it redefines the *FISPQs*. In Europe, the "Registration, Evaluation, Authorisation and Restriction of Chemicals"[5] (REACH) makes industry responsible for managing products that imply chemical risk and providing users with safety information. At the same time, a growing number of products, especially biocides, are having their use controlled. These are important measures from the point of view of sustainability that might have an influence on the competitiveness of exporting sectors in Europe. At least in theory, the system incorporates mechanisms that make it accessible to small and medium-size companies.

The impacts of REACH on the materials industry are important for various chains that use chemical products, like paints, adhesives, additives for cement materials, biocides, etc. This impact can be better evaluated by consulting the European official database[6] CP-DS: 'Legislation on substances in construction products'[7], or the private Swedish database BASTA[8], whose "declared objective is to remove from the construction and buildings market products

[5] Available at: <http://ec.europa.eu/enterprise/sectors/chemicals/reach/index_en.htm>. Accessed on: 10/30/2014.

[6] Available at: <http://ec.europa.eu/enterprise/construction/cpd-ds/index.cfm>. Accessed on:

[7] Available at: <http://ec.europa.eu/enterprise/sectors/construction/cp-ds/index_en.htm>. Accessed on: 10/30/2014.

[8] Available at: <www.bastaonline.se>. Accessed on: 10/30/2014.

containing hazardous substances, thus contributing to a non-toxic environment". The international tendency currently is not to include assessment of the toxicity of construction products within the scope of the *LCA* and the environmental product declaration. We are also seeing a tendency to abandon a sector view in favor of rules that are applicable to the whole industry.

Also with a view to controlling toxicity, the EU has established progressive maximum limits for the level of mercury in compact fluorescent lamps[9], which went from 5 mg in 2011 to 2.5 mg in 2013, with a benchmark figure of 1.23 mg. Despite reducing the total release of mercury, CO_2 reduction depends on the generation of electricity from coal, which will reduce. The regulation does not mention the minimum service life, which is undoubtedly going to have an influence on total emissions in the sector.

We also observe a concern with avoiding the growing surface of building materials exposed to rain and running water leaching hazardous chemical species, thus contaminating surface water and the water table. In the European experience, biocides and an incentive for incorporating waste in building materials as a strategy for reducing environmental impact come with this inherent risk, which needs to be controlled (TOGERO, 2004). This is a complex matter, which is internationally led by the Netherlands (VAN DER SLOOT, 1998) and secondly by Germany (SUSSET; GRATHWOHL, 2011) and for which the European Union has still not developed a harmonized solution.

Planning and estimating the service life of construction products

Minimizing the use of natural resources includes maximizing the service life of products. An estimate of the service life of different parts of a construction is essential for carrying out an assessment of the life cycle of the product and estimating the overall cost. Hypotheses relating to the service life have a direct influence on the conclusions of *LCA* studies (HOXHA *et al.*, 2014) and overall cost.

In recent years the advance of knowledge in the area has led to the preparation of ISO 15686 (Buildings and constructed assets – service life), a general methodology (applicable to any material) that enables the service life of materials and components under different use conditions to be calculated. This has been the basis for establishing the standard service life that is included in the environmental declarations of products in the French *INIES* system (<www.inies.fr>), among others.

Service life estimate is an integral part of the technical approval process for innovative products within the European Union.

Post-use: demolition and deconstruction

A modern strategy for reducing the environmental impact of constructions has involved not only the project of flexible buildings, which adapt to the variable needs of the user and to urban transformations over time, but also to the substitution of demolition for "deconstruction", a planned process (SCHULTMANN *et al.*, 2001) for maximizing reuse of the components of buildings that still have a significant residual service life (HOBBS; HURLEY,

[9] Available at: <http://ec.europa.eu/health/scientific_committees/opinions_layman/mercury-in-cfl/en/mercury-cfl/index.htm#5>. Accessed on: 10/30/2014.

2001). Recycling, therefore, is exchanged for reuse, making it possible to design a project that facilitates deconstruction.

Another tendency has been the taxing (and even banning) of construction waste disposed of in landfill sites. In Japan there is legislation (Construction Material Recycling Law) that obliges the construction company to send at least 95% of the mass of building products for recycling, with the exception of some, the full recycling of which is compulsory[10].

Innovation in materials and components for sustainability

We are also seeing an international trend for accelerating innovation aimed at sustainability in building materials and products. This is already obvious in the search for more eco-efficient solutions for serving this new market.

Generally speaking, innovation consists in an innovative combination of already existing products. Such is the case with solutions for buildings that are more than 10 stories high that have structural walls and floors made of wood, called "glue laminated timber" (**<http://www.clt.info>**) and of ultra-high performance concrete, which allow for a significant reduction in the mass of materials, with a consequent reduction in the environmental impacts of construction and an increase in service life (HABERT *et al.*, 2013). Improvements in the use of materials is also the order of the day with advanced concepts of the "functionally graded" and "bio-inspired" materials that are being used in construction. The application of these concepts on an industrial scale has been making it possible to spread digital production techniques, like robotics and 3D printers. Commercially there are already machines capable of varying the spacing of reinforcing bars in reinforced concrete, in accordance with the planned stresses, which leads to gains of more than 25% in environmental impact and cost (ALLWOOD; CULLEN; CARRUTH, 2011).

But new biomaterials are also being employed: the use of algae[11] and fungi[12] and the production of new materials (thermal insulators, acoustic absorption and even structural materials) opens up new prospects for raw materials.

Another trend is the incorporation of functions that are additional to those traditionally found in construction solutions, such as self-cleaning glass and concrete, the integration of cells for generating photovoltaic energy in roofing tiles and glass, the development of durable cold surfaces, which not only save energy in buildings but also help cool the planet, and phase change materials that add thermal capacity to construction systems without any increase in mass, etc. The search for energy efficiency and for zero net buildings has been important for encouraging innovation in materials.

The European Union currently has an eco-innovation project aimed at materials in general, which reveals the innovation dynamic that exists in construction[13].

The need to reduce the contribution of building materials to climate change is also the order of the day, particularly for materials produced on a large scale, like steel and concrete (DAMINELI; PILEGGI; JOHN, 2013).

[10] Available at: <https://www.env.go.jp/en/laws/recycle/09.pdf.>. Accessed on: 10/30/2014.
[11] Available at: <http://www.google.com/patents/US20110307976>. Accessed on 10/30/2014.
[12] Available at: <http://content.time.com/time/magazine/article/0,9171,1957474,00.html>. Accessed on 10/30/2014.
[13] Available at: <http://ec.europa.eu/environment/eco-innovation/index_en.htm>. Accessed on 10/30/2014.

4. Recommendations for preparing public policies

This topic will present public policy recommendations that, based on the limits of the study carried out, were considered a priority and capable of being implemented. However, as evidenced by the diagnosis, there is a large number and wide diversity of possible public policies and the choices must undergo a political assessment, not only by state agencies but also by society.

Combatting informality

Among the many important actions for improving the building materials chain, combatting informality is without doubt the most important within the panorama of Brazil, since informal companies are not affected by policies aimed at sustainability. What is more, the informal sector may even become more economically competitive when there is an increase in costs for the formal sector because of regulations.

The experience accumulated from use of the *PBQP-H* methodology is valuable. So the suggestion is to systematically expand the *PBQP-H* so that it covers environmental aspects and a greater number of production chains. Support for small and medium-size companies could make it feasible to extend the program for fighting non-compliance to sectors that have as yet not managed to introduce any indicators. Illegal timber extraction is a particular case of informality that needs a specific approach. These actions must always be combined with mechanisms that help producers, particularly the small and medium-size ones, become part of the formal production chain.

The commitment of the retail sector to combatting informality within the scope of the *PBQP-H,* including via the *BNDES* card, might be an interesting option.

Consumers and the purchasing power of government can also be engaged. *CBCS's* materials and supplier selection tool is an example. It could be strengthened by regulating the public disclosure of environmental licenses indexed by *CNPJ*, making it feasible to have wide access to information that is already guaranteed by current legislation.

Competition from informal sectors, and more recently from imported products, makes it counterproductive to issue regulatory measures that increase production costs for the formal sector and only prejudice those formal manufacturers that are established in the country. In these cases it is recommended that economic incentive systems are introduced for those formal manufacturers that adhere to programs aimed at sustainability in construction.

Introducing life cycle tools

Making it feasible to analyze the environmental aspects of the life cycle in daily business and the formulation of public policies are essential for promoting cleaner production models. Support for the Brazilian Life Cycle Assessment Program (*PBACV*) is fundamental for sustainable construction. But as the European experience and the on-going ISO standardization show, the *LCA* tool and its most important application, the Environmental Product Declaration, need to be simplified so that its use in the construction sector grows.

It is proposed that the Modular Life Cycle Assessment proposal should be supported, which enables companies and sectors to introduce the *LCA* concept in an evolving way, starting with the minimum scope module, comprising (a) CO_2, (b) energy; (c) water; (d) waste and (e) number of materials. This could be expanded to include any chain that is judged to be necessary. This proposal, which is consistent with the ISO methodology, was prepared initially by the *CBCS* and has already been presented by the coordinating body of the building materials area (*Abramat*, *FIESP/Deconcic*) to the coordinators of the *PBACV* and tested in the concrete block chain.

The introduction methodology includes working with the production chains, since it is based on the participation of a large number of companies, including small and medium-size ones, thus generating a benchmark in the Brazilian market. It also becomes part of the anthropic greenhouse gas emissions inventory and mitigation policy and of cleaner production strategies. It would also allow government bodies and companies to monitor performance with a simplified but relevant set of environmental indicators.

To make the system more attractive to companies, it must include the Environmental Product Declaration methodology, which is checked by a third party within the terms of ISO standardization.

The introduction of the *LCA* tool makes it possible to have public policies that oblige all advertising that claims a lower environmental impact to be proved by carrying out an evaluation of the product's life cycle. This has the potential for reducing the "greenwashing" that we see today and promoting healthy, isonomic competition based on environmental development.

It is also necessary to promote the development of governance for the system so that it becomes society policy. A critical aspect is the inclusion of these data on a public database that is compatible with BIM platforms, something that will require coordinating with tool developers.

Minimizing the consumption of natural resources and waste management

Many of the environmental problems of the building materials' chain are associated with the large quantity of resources involved, which implies the generation of a large amount of waste throughout the whole production chain. Minimization of the consumption of natural resources is, therefore, a priority. It involves a series of actions, including: (a) maximizing the service life of components and buildings; (b) strategies for reducing construction losses; (c) improvements in the management process and an increase in waste recycling, the latter being closely integrated with the National Waste Policy.

Policies for maximizing the service life of buildings and infrastructure are a priority, given their economic and environmental potential. They involve the consolidation of tools for the service life project; this is an item that is aligned with the current Performance Standard and fundamental for introducing the *LCA* tool in the sector. Also required are the creation of a laboratory infrastructure, information databases and human resources for supporting materials' manufacturers, project architects and construction companies. It involves encouragement for adopting flexible project strategies that not only increase service life, but improve the quality of life of the customers of social housing programs, like My House, My Life.

There are various strands to the policies for reducing the loss of materials in construction. An important policy is that of promoting the industrialization of construction, understood in its broad sense, including the use of more elaborated materials, like ready-made concrete and plasters and the use of assembly-based construction systems. Another is the use of the purchasing power of the state for promoting a modular construction system in the supply and project chain.

Policies for encouraging the management of waste are needed to make it feasible to introduce Conama Resolution 307/2002 and its subsequent alterations and also the National Solid Waste Policy. This policy is undergoing initiatives to make Conama resolutions more effective, particularly as far as concerns the management of hazardous waste, the introduction of management systems that are adequate for the size of our cities and incentives for deconstruction, which allows for the reuse of the materials generated. But it must also seek to create incentives for establishing businesses directed at the recycling of Class A construction waste, which is still marginal in Brazil.

Fiscal policies need to be developed that encourage more sustainable solutions, particularly for promoting the industrialization of construction, which needs to compete with environmentally less efficient activities that are carried out on construction sites, and in the effort to provide construction waste recycling activities with scale. As these activities today do not occur on any large scale (little or no tax is collected) this is a zero cost mitigation initiative.

Human health and building materials

Incentives for the preparation of the Chemical Products Safety Information Sheet (*FISPQ*) for materials that may contain chemical species that are harmful to human health can have a very important impact on reducing toxicity for workers and users and also improve the disposal of waste that is considered potentially hazardous (Class D of Conama 307).

Policies aimed at promoting the air quality of buildings are necessary over the short-term to face up to the reduction that has occurred in the traditionally high rates of ventilation.

The development of a general policy aimed at controlling hazardous substances must be both a short and long-term strategy.

Education and professional training

In education and professional training real encouragement must be given to training human resources at all levels, especially at the higher level. Civil engineering and architecture teaching syllabuses certainly need updating in such a way as to include the dimensions of materials' sustainability. An important alternative would seem to be a specialization course to be created in the architecture and engineering areas aimed at the selection and specification of materials and components.

Promoting eco-innovation

Innovation is the main way of generating the wealth of a nation. The result of Brazil's global leadership in biofuel (ethanol) technology reveals the potential of this strategy. Over the last few years Brazil has developed a coherent policy for encouraging innovation. The establishment of an eco-innovation program aimed at civil construction could boost the sector, allying the reduction in the country's environmental impact with Brazilian companies gaining in international competitiveness.

Assessment matrix of suggested policies

The following Tables give a summary of the public policies suggested in this document. For each measure indicated we show the impact that its introduction would have on the sustainability of the sector. The Tables seek to prioritize the public policies that are presented in order to guide their introduction over the short, medium and long-term.

TABLE 10 – PUBLIC PLANNING AND MANAGEMENT POLICIES

	Policies – planning and management	Impact
1	Strengthening the *PBQP-H*	High
2	Incentives for manufacturers that adhere to sustainability programs	High
3	Promotion of industrialization in construction	High
4	Support for the development of the *PBACV*	High
5	Support for small and medium-size companies	Medium
6	Strengthening the *CBCS* materials and supplier selection tool	Medium
7	Governance development of the environmental declarations system by *LCA*	Medium
8	Promotion of modular construction systems	Medium
9	Introduction of waste management that is adequate for the size of cities	Medium
10	Incentives for deconstruction	Medium
11	Incentives for the setting up of businesses for recycling Class A waste	Medium
12	Fiscal policies that encourage more sustainable solutions	Medium
13	Incentives for the preparation of *FISPQ* for potentially harmful materials	Medium
14	Promotion of internal air quality	Medium
15	Obligation to prove environmental gains before allowing advertising	Low
16	Initiatives for making the management of hazardous waste more effective	Low
17	Control of chemical substances that are hazardous to health	Low

TABLE 11 – PUBLIC POLICIES FOR TECHNOLOGICAL RESEARCH AND DEVELOPMENT

	Policies – technological research and development	Impact
1	Support for the modular *LCA* proposal	High
2	Creation of the Environmental Product Declaration methodology	High
3	Consolidation of tools for determining the service life of the project	High
4	Establishment of the eco-innovation program aimed at construction	High
5	Incentives for adopting flexible project strategies	Medium
6	Integration of the environmental declaration system by *LCA* with *BIM*	Medium

TABLE 12 – PUBLIC EDUCATION AND TRAINING POLICIES.

	Policies – education and training	Impact
1	Updating engineering and architecture syllabuses	Medium
2	Creation of specialization courses for professionals already active in the market	Medium

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List of acronyms

ABRAFAC	Brazilian Facilities Association
ABRAMAT/FIESP-Deconcic	Brazilian Building Materials Industry Association / Federation of Industries of the State of São Paulo – Department of the Construction Industry
LCA	Life Cycle Assessment
ANA	National Water Agency
ANEEL	National Electricity Agency
ARSESP	Sanitation and Energy Regulatory Agency
Asset rating	Physical installations assessment
BIM	Building Information Model
BPIE	Buildings Performance Institute Europe
CAESB	Environmental Sanitation Company of the Federal District
CBCS	Brazilian Sustainable Construction Council
CCA	Chromated copper arsenate
Compesa	Pernambuco Sanitation Company
COP	Performance coefficient
COV	Volatile Organic Compounds
CPD	Continuing Professional Development
Datacenters	Data processing centers
DECs	Display Energy Certificates
DEP/NY	Department of Environmental Protection of New York
DOE	Department of Energy of the United States
Dual-flush	Double flush action
EEGM	Energy Efficiency Guarantee Mechanism
Embasa	Bahia Water and Sanitation Company S.A
EPA	United States Environmental Protection Agency
EPAI	Industrial Water Production Station
EPBD	Energy Performance Buildings Directive
EPCs	Energy Performance Certificates
EPUSP	Polytechnic School of the University of São Paulo
Feed-in tariffs	Payment of subsidies throughproof of micro-generation in loco
FISPQ	Chemical Products Safety Information Sheet
GBPN	Global Buildings Performance Network

GDA	Water Demand Management
GHS	Globally Harmonized System of Classifying and Labeling Chemical Products
GLP	Liquefied Petroleum Gas
IBGE	Brazilian Geography and Statistics Institute
ICMS	Tax on the Circulation of Goods and Service Provision
IEA	International Energy Agency
ILCD	International Reference Life Cycle Data System
INIES	French National Database on the Environmental Impacts of Products and Services
International Building *Code*	United States Building Code
IPEEC	International Partnership for Energy Efficiency Cooperation
IPI	Tax on Industrialized Products
IPPIC	International Paint and Printing Ink Council
IPT	Technological Research Institute
IPTU	Urban Building and Land Tax
IRC	Colors Reproduction Index
LEED	Leadership for Energy and Environmental Design
M&V	Metering and Checking
MCMV	My House My Life Program
MCTI	Ministry of Science, Technology and Innovation
MEPs	Minimum energy performance from equipment
NBR	Brazilian standard
PBACV	Brazilian Life Cycle Assessment Program
PBE of INMETRO	Brazilian Labelling Program of the National Institute of Metrology, Quality and Technology
PBE Edifica	Brazilian Labelling Program for Buildings
PBQP-H	Brazilian Housing Quality and Productivity Program
PEE	Energy Efficiency Program
PLANSAB	National Sanitation Program
PMSS	Sanitation Sector Modernization Program
PNCDA	National Program for Combatting Water Waste
PNSE	National Environmental Health Plan
Procel	Brazilian Energy Efficiency Information Center
PROESCO* of the *BNDES	Support for energy efficiency projects of the National Development Bank
PSQs	Sector Quality Programs
PURA	Rational Water Use Program

REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
Rebate programs	Research and selection of on-going economic incentive programs
Sabesp	Basic Sanitation Company of the State of São Paulo
Saneago	Sanitation of Goiás SA
SAS	Solar heating system
SE4All	Sustainable energy for all
SEER	Seasonal Energy Efficiency Rating
SENAI	National Industrial Apprenticeship Service
SiAC	Construction Service and Work Companies Compliance Assessment System
SiMaC	Materials, Components and Construction Systems Companies Qualification System
SIN	National Grid System
SiNAt	National Technical Assessment System
SNIS	National Sanitation Information System
Survey Monkey	Platform for virtual questionnaires
Tep	Oil equivalent in tons
Water Sense	American EPA program
Zero Net	Nil balance

CBCS
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Construção Sustentável

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