Are current building regulations adequately advancing sustainable buildings? If not, what is missing, and how should they be changed? (Part II)

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Abstract: *This session brings together policy-makers, government officials, researchers and others to present perspectives on how innovation in building regulation and control, such as performance-based approaches, are currently being used to advance sustainability concepts in buildings, whether we are doing enough, and where and how we might see further innovation in the coming years. In this grouping of session papers, representatives of the Inter-jurisdictional Regulatory Collaboration Committee (IRCC) and the International Council for Research and Innovation in Building and Construction (CIB) Task Group 79 discuss a range of policies implemented in their countries and/or the focus of research and development in their respective countries. Related papers can be found in the corresponding set of session papers (Are current building regulations adequately advancing sustainable buildings? If not, what is missing, and how should they be changed? (Part II)).*

Keywords: *building regulatory systems, building control, performance-based, sustainability, climate change, resiliency*

Impact of energy efficiency goals on systems of building regulations and control

Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee

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H.J. VISSCHER and F.M. MEIJER, OTB Research for the Built Environment, Faculty of Architecture and the Built Environment, Delft University of Technology, Delft, The Netherlands (h.j.visscher@tudelft.nl) – *Impact of energy efficiency goals on systems of building regulations and control*

Abstract: *Considerations of climate change, but also other political and economic reasons urge for the reduction of use of fossil fuels and the minimization of environmental impact by the built environment. The energy saving potential of the building stock is large and considered to be the most cost efficient sector to contribute to the CO2 reduction ambitions. Goals set by the European Union are to build net zero energy buildings in 2020 and to reach a neutral energy building stock by 2050. As long as the price of renewable energy is still not competitive with fossil energy, the energy saving goals can only be reached by strict governmental policies. In Europe the Energy Performance of Buildings Directive and the Energy Efficiency Directive are driving forces for EU Member States to develop and strengthen energy performance regulations for new buildings and energy performance certificates (labels) for the building stock. The goal of this paper is to analyse the consequences of these developments on the systems of building regulations and control. It appears that, apart from adding new subjects, these new and very ambitious goals require systemic innovations in the regulatory systems. The current structures and approaches might not be adequate to deal with the new challenges. This is concluded from ongoing research that shows that aims of regulations in general and energy saving goals in particular, are hardly realized in practice.*

Keywords: *Energy Saving, Energy Performance, Building Stock, Building Regulations, Building Control*

Introduction

Climate change mitigation is maybe the most important driver for the ambitions to reduce the use of fossil fuels. There are also other reasons for implementing energy efficiency policies in the EU and its Member States. These include the wish to diminish the dependency on fuel imports, the increasing costs and the fact that fuel resources are limited. The European building sector is responsible for about 40% of the total primary energy consumption. To reduce this share, the European Commission (EC) has introduced the Energy Performance of Buildings Directive, the EPBD (2010/31/EC) and more recently the Energy Efficiency Directive (EED – 2012/27/EU). These frameworks require Member States to develop energy performance requirements for new buildings, a system of energy performance certificates for all buildings and policy programmes that support actions to reach the goals like building only 'Nearly Zero Energy Buildings (NZEB)' by 2020 and realizing an almost carbon neutral building stock by 2050. Formulating ambitions and sharpening regulations are relatively easy to do. Technical solutions are currently available to realise the NZEB standard in building projects and more and more projects of this kind are being build. There is quite some evidence however that the mainstream of building processes does not lead to the pre-defined quality or that the instruments are not adequate to reach the goal. What is perhaps even more important in this respect is that focus predominantly should be directed on the existing building stock. About 75% of the buildings that will make up the housing stock in 2050 have already been built today. This paper sketches the main developments in the field of building regulatory systems and building practice in the context of the increasing energy saving target, both for new as well as for existing dwellings. The main question addressed is whether the current regulations and forms of building control are adequate to realize the energy saving goals set by the EU and its Member States.

Developments in building regulatory systems

Building regulations are continuously the subject of debate. On the one hand regulations should be minimized to reduce the administrative burden on citizens and businesses. On the other hand new quality themes emerge that require regulatory intervention. Energy and climate change is such a theme. The European Union and its Member States have developed regulations and enforcements schemes that ensure very energy efficient new buildings and instruments that stimulate the improvement of the existing stock. Although the general development in European countries leads to less government intervention in the building sector, in the field of energy efficiency the number of regulations increases and become more stringent. Currently in the Netherlands the debate is very alive. The desire for deregulation is leading to the opinion that greater emphasis should be placed on the responsibility of property owners, which could lead to less governmental intervention. However, the existing forms of quality control for private actors in the Dutch building industry appear to be not adequate enough. Incidents occur and the physical quality sometimes falls short of the expectations. As the CO2 reduction and energy efficiency targets increase, stronger regulations and accurate building control become a priority.

The realisation of required energy performances in practice

In 1995 energy performance regulations for space heat and cooling of newly built constructions were introduced in the Netherlands. It consist of a standard for the calculation method which is called the Energy Performance Norm. The norm results in a non-dimensional figure called the Energy Performance Coefficient (EPC*). Every few years the level of this Energy Performance Coefficient was decreased, representing a lower energy use demand for heating. In 2020 new dwellings must be energy neutral. Since the introduction only a few studies were conducted to assess the effect of the regulations on the actual energy use. The samples were of limited size as well. Two studies found no statistical correlation between the energy performance coefficient level and the actual energy use per dwelling or per square meter. Analysis of the WoON (2009) survey, (that was carried out on behalf of the Dutch government in 2006 containing a representative sample of 5000 dwellings), also found no correlation between the different levels of the energy performance coefficient and the actual energy use per dwelling and per square meter (see Figure 1). Guerra Santin (2009, 2010) compared the actual and expected energy consumptions for 313 Dutch dwellings, built after 1996. The method included an analysis of the original EPC* calculations that were submitted to the municipality as part of the building permit application, a detailed questionnaire and some day-to-day diary's. These combined approaches generated very detailed and accurate data of the (intended) physical quality of the dwellings and installations, about the actual energy use (from the energy bills) and of the households and their behaviour. The dwellings were categorised according to their EPC*.

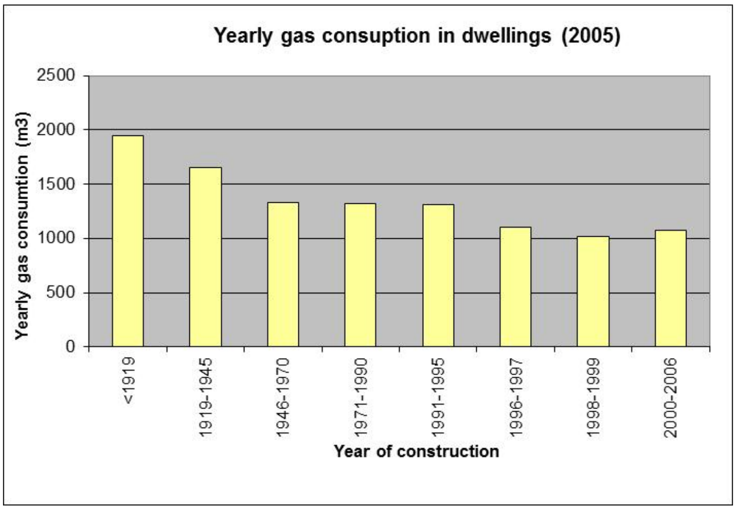

Figure 1 Yearly gas consumption in m3 in Dutch dwellings (WoON 2009) (note: non linear proportions)

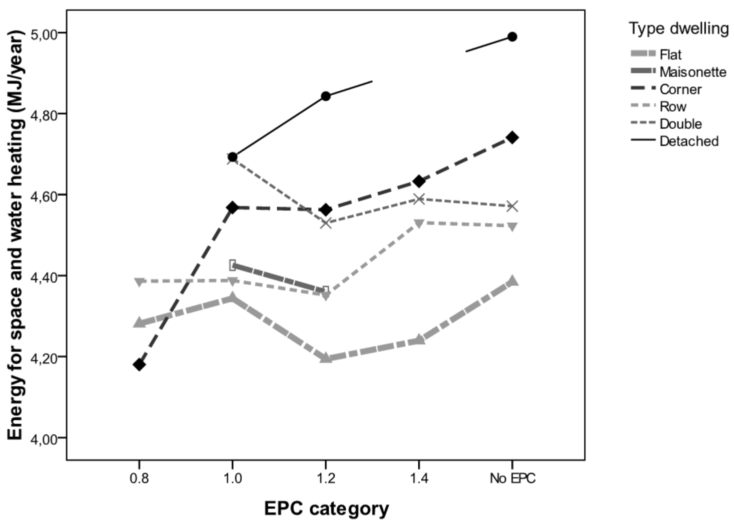

Figure 2 Actual energy use in relation the Energy Performance Coefficient per Type of dwelling (Guerra Santin, 2009)

In energy inefficient buildings with a high EPC*, actual energy consumption for heating was almost twice lower than expected. Whereas in buildings with a high energy efficiency, the expected and actual energy use coincided much better. Due to the relatively small sample size, the differences between the actual heating energy of buildings with different EPC* values were insignificant. Nonetheless the average consumption was consistently lower in buildings with lower EPC*. Guerra Santin found that building characteristics (including heating and ventilation installations) were responsible for 19% to 23% of the variation in energy used in the recently built building stock. Household characteristics and occupant behaviour seemed to be responsible for 3% to 15% of the total variance. On the basis of our study and other literature studies one can state that building characteristics, household characteristics and occupant behaviour altogether are responsible for at most 38% of the variation on energy consumption of dwellings built after 1995. Therefore at least 62% of the variation in energy use was unexplained by theoretical performance and behaviour and must be caused by other reasons.

There are indications that some of the explanation could be related to the fact that buildings are constructed differently in practice than is described in the design documents and that HVAC services operate in very different conditions than assumed beforehand. Nieman (2007) showed that in a sample of 154 dwellings, 25% did not meet the energy performance requirements because of incorrect calculations. Nevertheless the building permit was issued. In 50% of the dwellings, the realization was not in accordance with the design. These results match with findings about inadequate performance of both building control as the building industry in the Netherlands and other countries (Meijer e.a. 2002, 2006, 2008). Taking into account the above findings, one can have some doubts if a further tightening of the energy performance regulations will lead to a better energy performance in practice. Perhaps there are other and more efficient solutions to decrease the energy consumption of newly built dwellings in practice. Important ingredients of the solution are: ensuring that appliances and installation are correctly installed, monitoring the calculated performances in practice; enlarging the know-how and skills of building professionals and putting in place an effective and efficient building control and enforcement process.

Policies and instruments for energy reduction in existing dwellings

It is relatively easier to apply energy saving measures in newly built buildings. However the largest energy saving potential is in the existing building stock. On average new dwellings add less than 1 per cent per year to the housing stock. The most important policy tool required by the EPBD in the European Member States is the issuing of Energy Performance Certificates (or EPC's). The EPC gives an indication of the energy demand necessary to realise a certain average temperature in the building and depends on physical characteristics of the building. The EPC indicates the energy demand for heating and cooling. The certificate has no mandatory implications in the sense that owners could be forced to improve their buildings to certain levels. Nonetheless it could be a crucial instrument for benchmarking and formulating policy goals. Building owners in all Member States have to produce an

EPC for a building at the moment it is sold or re-rented. This is not yet current practice everywhere, mostly due to lacking of enforcement. This especially applies to the private housing stock. In the Netherlands however, the complete social housing stock is labelled with an EPC. The social sector in the Netherlands is still relatively large (35%) and well organised. For the social housing stock the EPC's are collected in a database. With this database the progress of the renovation practices can be monitored. Besides that the relation between the EPC's (with the calculated energy use) and the actual energy use can be studied. A few years ago the sector formulated ambitious programmes, but these have been scaled down because of several reasons. The economic crises reduced the financial position of the housing associations. The housing market also dramatically slowed down which also affected the funding for renovations because this largely depends on the sales of property. Also it proved to be difficult to get approval of tenants for renovations that require an increase of the rents (70% of the tenants have to agree). It is hard to assure the saving of energy costs resulting of the improvement of the dwellings. All in all the progress of renovations and energy upgrading measures stays far behind expectations and formulated ambitions in 2008 when most of the policies, covenants and improvement programmes were set up.

Besides the physical characteristics, the actual energy use is largely influenced by the use and behaviour of the tenants. Some preliminary figures demonstrate the difficulty in 'forcing' reduced energy use by improvements of dwellings. The dwellings with the worst EPC (G) in practise use far less energy as expected, while the most advanced dwellings (A) use much more. This is probably due to a combination of the rebound effect and an increase in comfort level of the dwellings (Majcen et al 2013a, 2013b) and underperformance of the buildings and installations. Figure 3 shows the actual and theoretical gas consumption per dwelling per EPC. In the homeowner sector the issuing of EPC's stay yet far behind the expectations. This means that the intended purposes are not reached. When EPC's become common practice they could affect the sales price. There is no enforcement system in place to guarantee that only buildings with an EPC can be traded on the housing market.

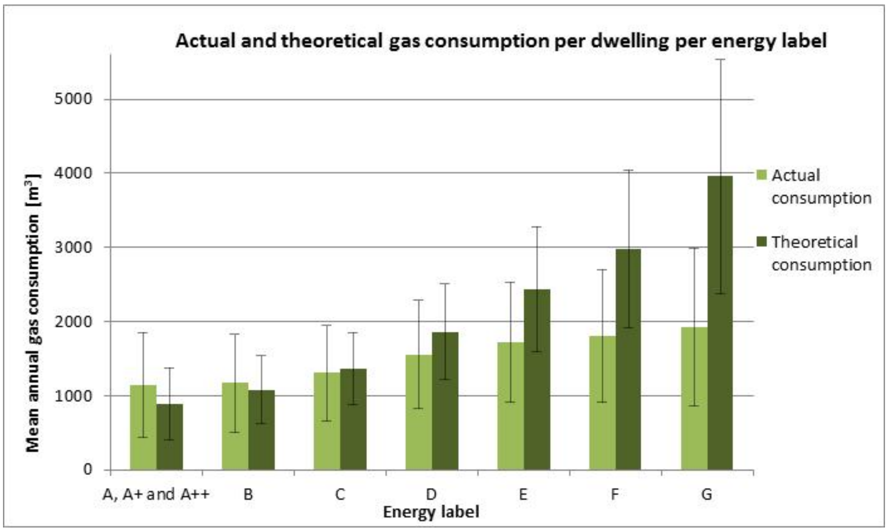

Figure 3 Actual and theoretical gas consumption in Dutch dwellings (Majcen et al., 2013a)

Impact on the systems of building regulations and control

Without any doubt there is a necessity to drastically reduce the use of fossil-fuel energy sources by reducing the demand for energy and switching from fossil to renewable sources. Buildings account for 40% of Europe's energy consumption and three-quarters of the floor area of the building stock is residential. The targets are clear and the technical solutions are available. Severe insulation and product innovations can reduce the energy demand for heating and cooling for a large part. The remaining energy demand can be delivered by renewables like sunlight and heat, district heating, heat pumps, etc. The remaining electricity demand for appliances can in the first place be reduced by further product innovation and then be provided by photovoltaic panels. There are no reasons not to apply these solutions in new buildings at a large scale on the short term. Evaluations of the current practice show however that there is a lot to be gained here. To improve this situation it has to be assured that constructions and installations are installed properly and in such way that they are not vulnerable for unpredictable or misuse by the occupants. This will set demands on both the construction industry as on the control and enforcement process (and the parties responsible).

Better quality control during the whole process is absolutely essential. It is quite feasible to charge the building professionals with this task. Our international comparative research into building regulatory systems shows a tendency to put more emphasis on the responsibilities of owners and private parties (instead of local authorities) to control and ensure the minimum quality of construction works. For a successful transition towards energy neutral construction stricter demands must be set on the knowledge and skills of these building professionals (designers, engineers, installers, constructors, etc.). They will have to use new techniques and improve the quality and accuracy of the work. This means that they not only will have to improve their operating procedures but also have to implement performance guarantees. Owners and users will require quality guarantees from the designers, installers and constructors. Certification and accreditation of parties, processes and products will become more important for building processes in general. For the realization of high energy performance standards, a reliable quality assurance system will be very important. In most countries that have some experiences with passive houses some form of performance guarantee and associated quality assurance scheme exists. It is important to study these examples.

For new constructions a successful transition lies easily within the bounds of the possible. The existing building stock forms a far greater challenge. The potential energy savings are far bigger, but the barriers to overcome are also higher. As stated before almost three quarters of the future housing stock (2050) has already been built. Studies show however that it is hard to increase the rate and depth of energy renovations of the existing stock. Actual energy (and financial) savings in renovated dwellings stay behind expectations because of rebound effects. There are important barriers. Many owners believe that the benefits of the measures do not outweigh the costs. Besides that, the cost of improving the energy performance of a dwelling does not (proportionally) increase the value of the dwelling.

We are faced with the difficult task to increase the energy renovation pace. The question is how this process can be accelerated. Maybe there is still room for further smart product development. Innovative products that that contribute massively to the reduction of energy demand, that are cheap, easy to apply and to handle by occupants and users. The fast decrease of the price of PV cells is promising.

Climate change and the related demands on buildings will have a profound impact on the design of building regulatory systems. The past few years OTB – Research for the Built Environment has been involved in studying alternative visions on building regulatory systems in international comparative projects. What we see in most countries are discussions (or sometimes even concrete developments) where the balance slowly shifts from:

- Command and control regulations towards more economic incentive based policies;
- Public control and enforcement towards a more dominant role of private parties/building professionals (together with the materialisation of far more robust and reliable certification and accreditation schemes);

- A strong focus on control of the design to monitoring of the building process and testing of the quality of the final building and post occupancy monitoring.

At the same time the role of regulations for existing buildings come under scrutiny and from a range of stakeholders attempts are undertaken to search for solutions. Instant solutions are not easy to give. None the less along the most probable solutions will move in the directions sketched above.

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Perspective of the Building Sustainability Regulatory Evolution in Spain: From Prescription to Performance

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Abstract: *The very last few years have seen a huge change in the regulations affecting building sustainability in Spain and the present offers a challenging panorama as the amount of effort and money involved in this legal transition asks for a critical evaluation in terms of effectiveness. The first results of the implementation of the 1999 Building Act and the 2006 Code have coincided in time with a deep economic crisis affecting specially the building activity in the country, therefore not allowing an easy evaluation of their impact. In addition, the EU has set very ambitious objectives in this subject that urge an optimization of the requirements, methods and tools required to face the problem. The efficiency of some of the requirements in the Code, that were purely prescriptive, has been questioned by practitioners and code officials. The regulations and the practice are moving quickly from prescription to performance.*

Key words: *Sustainability, regulatory evolution, requirements, prescription, performance, verification methods, verification tools*

1. Introduction. Global perspective

Until early in this century, by 2006, Spain did not have a unified single national Building Code. Different regulations formed an open framework based in a prescriptive approach. There were specific regulations for buildings, named Basic Building Standards ("*Normas Básicas de la Edificación*", NBEs), which formed a series of separate regulations dealing with structural, noise protection, thermal insulation, energy performance, protection against moisture, and fire safety requirements. NBEs were approved through royal decrees by the Government.

In 1999, the new Building Act established a new building regulatory system. The Act aims to achieve a better quality in building, so provisions determining the minimum quality levels of buildings, the professional competencies and responsibilities, and the liabilities and insurance requirements were all set out in the Act. In this way the Act proposes, in terms of objectives, the minimum "*basic building requirements*" regarding functionality, safety and habitability, which includes requirements on accessibility, structural and fire safety, safety in use, hygiene, health and environment protection, protection against noise and energy and thermal insulation. These general objectives just set and briefly defined in the Act [1], needed to be developed by the Government in a technical Building Code ("*Código Técnico de la Edificación*", TBC) referred as "Code" in the following [2]. The main objective of the Code was to supersede the old and obsolete framework by getting a modern, simple, and effective set of building regulations unified in a single Code comparable to the most advanced in the world. The Performance-Based approach, achieved in many developed countries was taken into account as much as possible, and served to arrange the Code around the so-called Nordic five-level hierarchy according with the IRCC guidance. Therefore, the Code initiates the evolution of the Spanish regulations from prescriptive to performance.

The intention of the regulator was to draft the Code in two parts: A first one, that includes the Code functional requirements and a second part, composed by the quantification of the requirements and the verification methods which include the official methods of fulfilment. The new Code had, as old NBEs had too, an "equivalence clause," which allows the designer (architect or engineer) and the director of the works to adopt solutions differing from those in the regulations, provided they prove by other means the fulfilment of the objectives in that regulation. The clause is aimed to allow anad encourage innovation, and also consider the importance of the Spanish professional's competence in the construction field.

2. Current regulations in Spain

The Code was approved in 2006 by Royal Decree 314/2006, of 17th March, as the new building regulatory framework that establishes performance-based basic requirements to be met by buildings, in terms of the essential requirements. The Code was intended to be as a well-organized normative framework and seeks to facilitate their application and fulfilment, in harmony with European regulations. The Code coexists with other technical regulations, such as the one on concrete structures (that includes both building and civil engineering), the seismic regulations, those on installations like heating and cooling facilities, gas, electrical equipment, etc. Crossed references are in both worlds.

2.1. The Building Code and Sustainability

As said before, in concept, the Code was developed in two parts. The first one includes general provisions and a detailed expression (in qualitative or quantitative terms) of the basic requirements laid down in the Act, and the second part deals with the fourth and fifth levels in the Nordic arrangement: methods of verification or compliance and acceptable solutions. The requirements of the Code shall be considered as minimal, without prejudice to more stringent values which may be established by the competent authorities and which contribute to sustainability, taking account of the actual characteristics of their local environment, but in fact, actually this possibility rarely exists. Regarding the sustainability issues, the Code includes some requirements that contribute in general to protect the environment and some to limit the use of energy which indirectly contributes to lower CO2 emissions to the environment. But the environmental performance of a building is just only one aspect of its sustainability. The social and economic aspects of the building are also matters that should be taken into account as part of any sustainability assessment. Furthermore it is necessary to keep in mind that the Code applies exclusively to the building and its nearby environment.

The first environmental objective was to ensure a ‘rational use of the energy’ needed for the building to be run properly. This was to be accomplished through compliance with five requirements expressed in a performance-base: limitation of energy demand, maximum efficiency of heating and cooling systems, energy efficiency of lighting systems, a minimum solar contribution for domestic hot water, and a minimum photovoltaic contribution for electric energy. These objectives were stated in the performance approach as much as it could. In addition other requirements somehow related with sustainability were stated within other specific health protection basic requirements, such as disposal of waste, air quality, water supply, drainage of wastewater, and also protection against noise.

2.2. Updating Sustainability aspects of the Code

The Energy Performance of Buildings Directive [3] published in 2002, required all EU countries to enhance their energy regulations and to introduce energy certification schemes for new and existing buildings. With the adoption of the recast EPBD in 2010 [4], EU Member States faced new challenges, like going towards nearly-zero energy buildings by 2020 (2018 in the case of Public buildings). The updated Code needed therefore to rise the 2006 energy standards (for both new and existing buildings) to higher levels seeking to meet the ‘nearly zero-energy concept’ through increased energy efficiency of the building envelope and systems, and additionally with an increase of the already required contribution of renewable energy. This made necessary an updating of the Code Basic Document on Energy Performance (DB HE) towards a substantial reduction of the energy consumption in new buildings, approaching the EU directive with cost-optimal requirements and asking adequacy to the new requirements when retrofitting existing buildings.

By June 2013 the Code scope included in its Part I was amended by the new Act 8/2013 on Rehabilitation, Renovation and Urban Regeneration [5] which amended also the Building Act 1999. Both amendments are aimed to get a better application of both Act and Code in those interventions performed on existing buildings. New criteria on how the Code provisions must be taken into account in any intervention on existing buildings have been set. They are the principles of ‘not worsening’, ‘proportionality’ and ‘flexibility’. The classifications of types of intervention in building that are subject to regulatory enforcement have been also clarified in three categories: “reform works”, “changes of use” and “extension of buildings”. As said, the updating of the energy part of the Code is due mainly to the need to transpose part of the European Directive 2010/31/UE on energy efficiency in buildings, EPBD [6], but as well as the need to regularly update the Code, accordingly to the evolution of technology and demands of society, as it is claimed by the Building Act.

The new energy Code presents a remarkable increase in the level of energy efficiency of buildings with respect to the levels established in 2006, focusing towards the ambitious target of having 'nearly zero energy buildings, nZEB' by 2020. Some of the most significant changes are that the new performance requirements affect both the new construction and the interventions in existing buildings and that a new Code Section HE 0 has been introduced to incorporate a new requirement to limit the energy consumption depending on the climate zone and building use. Besides that a new draft modification in the Code which is still pending affects a lot of its parts. The main changes of the update are those focused to better regulate the fulfilment of the Code in rehabilitation of existing building. The main reason for the review is that the current application of the current Code in existing buildings was having quite complexity and has generated many doubts and questions among both professionals and municipal building controllers in charge of issuing building permits. The new set of criteria for the application of the Code in existing buildings has been drafted in order to achieve the maximum possible approach to an acceptable level of performance. The challenge that has been found is to establish how much the level of performance required for a new building can be reduced to an acceptable level in an existing building and whether it is possible to determine different levels of performance in every case. The classic structure of the Code upon the Nordic five-level hierarchy is being completed in Spain with many supporting documents that are not strictly part to the Code which are drafted to facilitate its use. These voluntary supporting documents permit to fulfil the requirements with more freedom by using the performance approach. An image of the current Spanish building regulatory framework is shown in Fig 1.

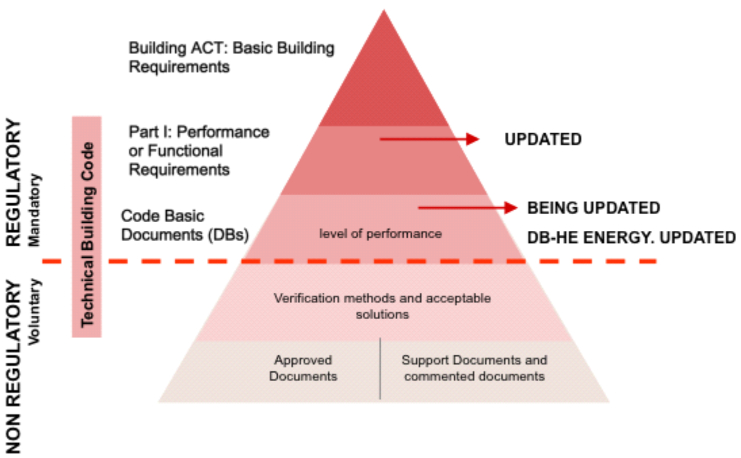

Fig 1. Code Hierarchy scheme

3. Standards about sustainability

In the recent years a set of new standards have been developed related with Sustainability of construction works. CEN/TC 350 is responsible for the development of voluntary horizontal standardized methods for the assessment of the sustainability aspects of new and existing construction works and for standards for the environmental product declaration of construction products. This frame includes environmental performance of buildings, building life cycle analysis, environmental products declaration and economic and social performance assessment. It is expected that in future the Code will increase sustainability requirements.

4. Future perspective

4.1 Sustainability aspects not considered in the TBC (CTE)

As Sustainability is becoming more and more essentially quantifiable, it makes up a good basis for a performance development. The current Energy Efficiency Certification in Spain [7], even with the problems detected along its development since it was initially introduced in 2007 and completed in the following years, is a good example of establishing performance groups that become evident for the stakeholders and the market. Nevertheless, some important issues regarding Sustainability have not been considered yet by the Code or if so, are not dealt with in a performance way, making very difficult its quantification. Table 1 shows a comparison between the sections contained in some recognized international codes, certification tools and the Spanish Code.

IgCC [8]	**GBCe** [9]	**BREEAM** [10]		**LEED** [11]		**TBC (CTE)** Requirements **Tools**	**P.**
Sections	Sections	Sections	Rating	Sections	Rating		
Jurisdiccional Requirements and Life Cycle Assessment	(The complete methodology is based on a LCA)	(Life cycle impacts in **Materials**) (Life cycle cost and service life planning in **Management**)		(Building life-cycle impact reduction in **Material and Resources**)			
Site Development and Land Use	Site and Location	Land Use and Ecology	**10**	Sustainable Sites	**10**		
Material Resource Conservation and Efficiency	Natural Resources	Materials	**12**	Material and Resources	**13**	SI-1, 2 HS1	
Energy Conservation and CO2e emission reduction	Energy and Atmosphere	Energy	**30**	Energy and Atmosphere	**33**	HE-0, 1, 2, 3, 4, 5 **LIDER** **CALENER** **CE3** **CE3X** **CERMA**	**X**
Water Resource Conservation, Quality and Efficiency	Natural Resources	Water	**9**	Water efficiency	**11**	HS-4, 5	
Indoor Environmental Quality and Comfort	Indoor Environmental Quality	Health and wellbeing	**10**	Indoor environmental quality	**16**	HS-1, 2, 3, 4, 5	
						HR **GUIA APLICACIÓN DB HR**	**X**
Commissioning, Operation and Maintenance	Service Quality	Management	**22**			All	
Existing Buildings	**X**					**Part 1**	
Existing Building Site Development							
	Social and Economic Aspects						
	Design Quality						
	Innovation	Innovation	**10**	Innovation	**6**		
		Waste	**7**			HS-2	

		Pollution	**13**			HE-2 HR HS3	
		Transport	**9**	Location and transportation	**16**		
				Regional priority	**4**		
				Integrative process	**1**		
		TOTAL	**130**		**110**		

Table 1. Comparison between different documents and the requirements in the Spanish TBC. An "X" in the last column indicates the existence of a performance frame at the moment

Some of the sections rated in these documents may not be directly considered by the Code, because they exceed their scale or are under the jurisdiction of local or regional governments. This is the case of transportation, regional development or the social and economic aspects. Others, like innovation or design quality, unless interesting, are difficult to regulate from a TBC perspective.

4.2 Sustainability aspects to be considered or changed in the Code

There is no much in the Code about materials and resources in addition to their proper selection to meet the technical standards. The use of a percentage of recycled or local building materials is not established and there is no a requirement for a life cycle assessment. Energy efficiency represents probably the most developed aspect as the last Code modification, in September 2013, has introduced a limitation in the not renewable primary energy consumption [12] for every climate zone in the country. This is obviously tied with the Energy Efficiency Certification, and several software tools have been developed for the purpose. Nevertheless some improvements may be done in the regulation of renewable energy systems to allow more flexibility. At this moment a percentage of hot water energy usage needs to be supplied by onsite solar heating equipment and solar photovoltaic systems are mandatory in some non-residential large buildings. The diversity in the Spanish climate conditions makes inefficient the fulfilment of some of the percentages required in some parts of the geography and a more flexible use of all these renewable resources including wind or geothermal systems and some heat pumps. It is proposed that only a minimum percentage of renewable energy shall be demanded, without a previous determination of the system.

Water is probably the less regulated aspect at this moment, especially if we consider its scarcity in many Spanish regions and the increasing demand of water. The requirements in the 2006 Code were too simple, probably a continuity of the former ones, and haven't been modified since then. On the one hand there is a need to reduce consumption. The water supply requirements, which demand separately hot and cold water minimum flows, ask for a total rate in the fixtures approximately double than the ones considered in the 'International Green Construction Code', IgCC. In addition there is only a demand of flowing reducing devices in public buildings. On the other hand there is a need to enhance reuse. There is a need for a clear definition of the different kinds of water in the buildings, specifying their possible reuse process. It is especially important to define their origin and their final use. It is suggested that a definition of gray water doesn't include flows from kitchen sinks or dishwashers in addition to water closers and urinals.

The indoor environmental quality is regulated by the Code sections HS3 and HR, but also by a different technical regulation on thermal installations in buildings, RITE 2007. Unless this regulation considers different air quality levels, the first one does not. The Code regulates the air quality only in residential buildings and car parks allowing both mechanical and hybrid systems for housing. The hybrid system, which in fact is a combination of natural and mechanical ventilation, requires intake air openings for a 0.7-08 air changes per hour for a medium size house and therefore, in addition to other infiltrations, represents a challenge for energy conservation in some regions. Mechanical systems for intake and extraction air with a heat recovery device have proved the best solution for the purpose. Other strategies, like the activation of the systems under occupant detection can combine adequate air renovation with reduced energy consumption.

In addition there is no a specific regulation for banned materials but it is suggested that some toxic or hazard materials could be listed, taking into account the relevant EU provisions in this field. Noise is considered a wellbeing requirement and unless a prescriptive procedure is established is required to be completed with post construction testing. The only aspect of waste disposal considered by the Code is the establishment of a specific space to collect ordinary waste in residential buildings, allowing in other uses a similar procedure. Some air pollution aspects, like materials toxicity and the emissions from building fires could be considered.

The existing building stock represents a real challenge at this moment. This is due to the poor performance of many of the existing buildings, built under none or very low standards and the necessity of renew the city centres. The recent Act 8/2013 of Rehabilitation, Regeneration and Urban Renovation has modified the Code to allow some flexibility in its fulfilment, but there is still a big lack of clear benchmarks for a clear interpretation. A good clarification and classification of the works is needed to allow both practitioners and code officials to reach agreement. The use of different alteration levels, as the ones considered in the International Existing Building Code IEBC [13], could be a good solution to face the problem. Some evaluation tools regarding the previous and reached building performance for different requirements like energy, health or safety, and the involving costs, could be a good help for decision. This will allow certain asymmetry in the works but ensuring some minimum performance levels in aspects that don't represent the main concern.

5. Conclusions

- The Spanish Code, CTE, does not consider, so far all aspects regarding Sustainability, if it is compared with some recognized Green Codes or Sustainability Evaluation Tools.

- Unless a big effort has been done in Energy Efficiency, under the EU regulations, other important aspects remain as were initially considered in 2006 and are essentially prescriptive. Some of them, especially regarding materials, water and indoor environmental quality, as those included in section HS1 need to be revised and changed towards a better performance characterization.
- Although there are some other aspects of sustainability that legally will not be enforced directly by the Code, it is important to recognize the existence and availability of some official tools on Sustainable characterization or Life Cycle Assessment.
- The improvement of the existing buildings stock represents the biggest challenge, due to its big number and their bad performance.

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Reviewing challenges between the need for government-subsidized housing in South Africa and the sustainability requirements of the National Building Regulations.

Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee

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Jacques LAUBSCHER, Department of Architecture, Faculty of Engineering and the Built Environment, Tshwane University of Technology, South Africa (laubscherj@tut.ac.za) – *Reviewing challenges between the need for government-subsidised housing in South Africa and the sustainability requirements of the National Building Regulations*

Abstract: *In Sub-Saharan Africa, building operations are estimated to be responsible for 56% of energy used. Between 1994 and 2014, the South African government built approximately 3.6 million homes, accommodating more than 11 million people. Despite this effort, official statements claim that 23% of South African population is currently living in an informal dwelling. In an effort to reduce costs, the erection of government-subsidized housing is partially exempt from the requirement of the National Building Regulations. This paper reviews the challenges between the need for government-subsidized housing in South Africa, the National Building Regulations and a passive design approach.*

Keywords: South Africa, National Building Regulations, government subsidized housing, low cost housing, passive design

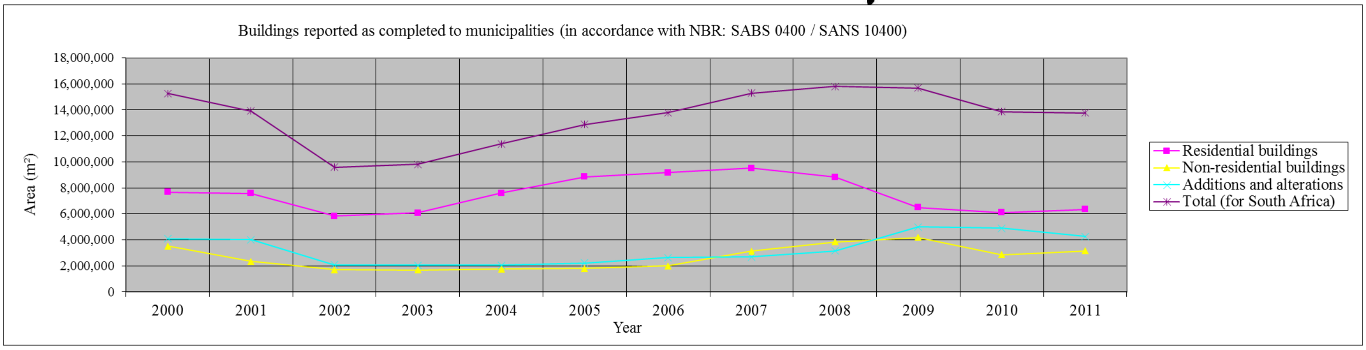
Introduction

The South African built environment could be divided into two specific parts, namely the formal and the informal sector. Unavoidably, this division is mostly based on economic standing. Housing forms the largest part of the informal segment. The aggregated per capita income of a household mostly determines whether a family is housed in a formal or informal structure. However, the formal and informal housing categories remain inextricably linked.

Current status quo

For the period 2000 – 2011, the government agency Statistics South Africa (Stats SA) reports the total completed building projects in South Africa at 161,058,295 m² [1]. The total area constructed in South Africa for the respective years is summarized in Figure 1:

Figure 1: Building reported as completed to South African Municipalities (2000 – 2011)

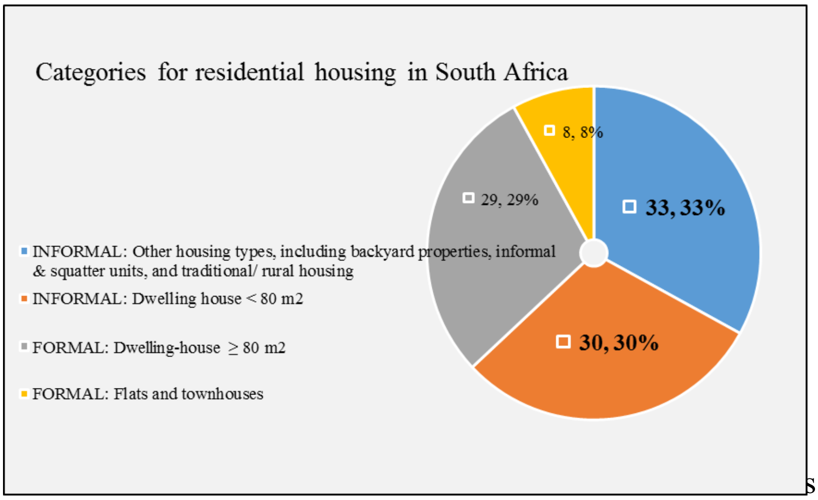


Three different categories are used by Stats SA to classify the built environment. During the period 2000 – 2011, the completed building area in South Africa for the respective categories are the following: [1]:

- Residential buildings: 90,050,494 m²
- Non-residential buildings: 31,936,026 m²
- Additions and alterations: 39,071,775 m²

The residential component is the largest contributor to the South African built environment. According to the definitions used by Stats SA, the informal component of residential buildings comprises both traditional- and informal dwellings. Using the context of its location, the informal dwelling is further divided into the Traditional dwelling/hut/structure made of traditional materials; the Informal dwelling in backyard; and the informal dwelling not in backyard. The extent of informal housing is more than 63% of the residential building category [2]. The various contributors to the houses in South Africa are summarized in Figure 2:

Figure 2: The sectoral contribution to residential buildings

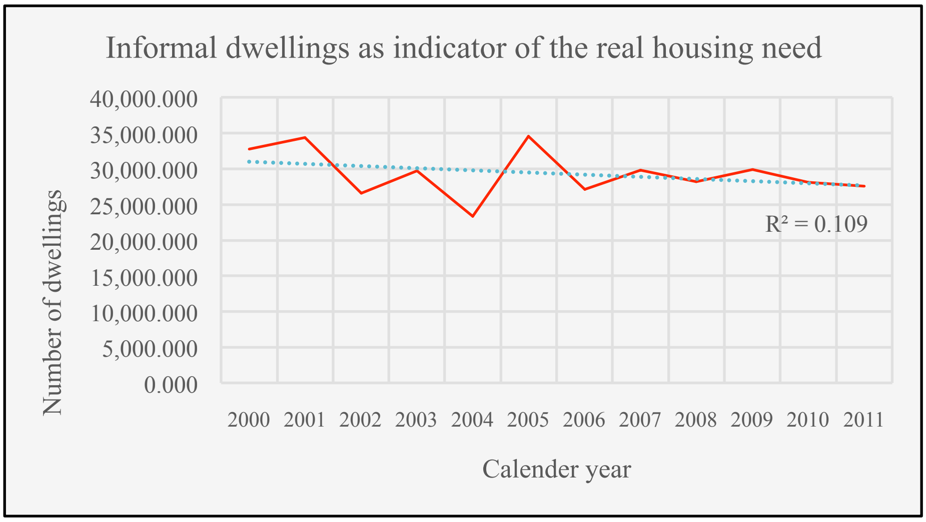


Real world problem

According to official statements, the South African government built 3 584 689 homes [3], accommodating more than 11 million people during the period 1994 - 2014. On 22 May 2013, the then Human Settlements Minister Tokyo Sexwale tabled a R28.1 billion budget before Parliament. According to Minister Sexwale, the "2013/14 financial year allocation signified the Government's determination to eradicate the problem of homelessness in the country" [4]. At the same occasion, the housing "backlog of 2,1 million houses for 8 to 10 million people," was highlighted [4]. Using the lowest subsidy and official backlog statistics, the current value of this shortage is an estimated cost of R232 billion (R232,987,755,000.00) or €16,5 billion (€16,514,405,062.16).

The number of informal dwellings is considerably more than the official housing backlog. There could be various possible reasons for the phenomenon of informal housing in SA. Nonetheless, it could be argued that the use of an informal structure (as a dwelling) should rather serve as an indication of the real housing need. When using information from Stats SA, the changing population statistics indicate an increase in urbanization and emphasize the challenges surrounding the housing backlog. Using the available data on informal dwellings from Stats SA, while excluding the number of traditional dwellings[1], the real housing need in South Africa is estimated to be more than 25 million units. In Figure 3, the number of informal dwellings are presented as the actual housing need [1].

Figure 3: The total number of informal dwellings for the period 2000 – 2011



Current subsidy for government subsided housing

[1] A traditional dwelling being a house that is constructed using traditional building materials.

There are various different categories of government-subsidized housing ranging in size from 40 m² – 70 m². The 40 m² *Stand Alone Residential Dwelling* is the most often used prototype. The current total *Individual Housing Subsidy Quantum* for the 40-m² dwelling is R160,573.00. This total is divided as follows [5]:

- R110,947.00 (€7,864.03) construction cost of the house,
- R43,626.00 (€3,092.25) for the services cost, and
- R6,000.00 (€425.29) for the raw land cost.

Table 1:Detailed cost breakdown of government subsidy for a 40 m² dwelling [5]

DETAILED COST BREAKDOWN OF THE STANDARD 40 m² HOUSE FOR PERSONS EARNING BETWEEN R0.00 - R3 500 /month or €0.00 - €248.08 FINANCED BY THE NATIONAL HOUSING PROGRAMME of SOUTH AFRICA (Implementation date: 14 April 201				
Cost element	Cost (ZAR)		Cost (€)*	
Earthworks	R	6,707.48	€	475.43
Concrete, Formwork & Reinforcement	R	10,780.37	€	764.12
Brickwork	R	15,528.48	€	1,100.67
Roof Structure	R	8,832.44	€	626.05
Ceiling and insulation	R	7,311.82	€	518.27
Windows [Standard]	R	4,092.34	€	290.07
Windows: Special LowE clear and opaque glass	R	3,991.19	€	282.90
Doors and Frames	R	6,558.00	€	464.84
Finishing and paintwork	R	10,637.98	€	754.03
Electrical	R	9,958.40	€	705.86
Plumbing and toilet	R	9,976.38	€	707.14
Total (Building costs)	**R**	**94,374.88**	**€**	**6,689.39**
P&G	R	8,578.67	€	608.06
Project manager	R	3,604.00	€	255.46
Clerk of works	R	3,089.00	€	218.95
Transfer cost	R	1,000.00	€	70.88
Beneficiary administration	R	300.00	€	21.26
Total (Project costs)	**R**	**110,946.55**	**€**	**7,864.00**
*Calculated using an exchange rate of R14.11 for €1.00 (23/05/20				

The National Building Regulations in South Africa

The National Building Regulations and South African National Standard (SANS 10400) (NBR) state the minimum obligation for the owner of a building. The requirements of the NBR is controlled when a proposed building plan is submitted to the LA for approval. Without the necessary approval, the construction and/or alterations to an existing structure cannot proceed. The NBR introduced in 2011 a new section titled SANS 10400 Part XA-Energy Usage in Buildings. The primary aim of Part XA is to address the spiraling energy consumption of South African buildings. The challenges with the necessary compliance to the revised requirements of the NBR are generally associated with higher building costs.

Government exemption from the National Building Regulations

The South African Government is one of the major land and building owners, but it remains largely exempt from compliance with the requirements of the NBR. Sections 2(3) and 2(4) of the amended *National Building Regulations and Building Standards Act, 1977* explicitly state that the Government is not obliged to submit plans for approval, but must only make a submission for information purposes before the commencement of building [6].

The latest revisions of the NBR introduced Category 1 buildings. Government subsidized housing resort under this category. A Category 1 building has a maximum floor area of 80 m^2; this building class allows different resistances to rain penetration, structural deflection limits, lower maintenance requirements and natural lighting levels, etc.

Revised Norms and Standards for government subsidized housing

The Department of Human Settlements reviewed the prescribed Norms and Standards for all government subsided houses in an attempt to address pertinent issues from the revised requirements of SANS 10400. Additional features were included, supplementing the original requirements of the government-subsidized house [5]. These included the installation of a ceiling with the prescribed air gap for the entire dwelling and the installation of above-ceiling insulation comprising a 130mm thick mineral fiberglass blanket[2] for the entire house, using smaller sized windows and installing special low Emissivity (clear and opaque) safety glass for all prescribed window types. The plastering of all internal walls and applying a form of rendering on external walls were also added.

Financial impact of additional cost items

The additional cost requirements applicable to the 40 m^2 house, amounts to 12 % of the building costs and approximately 10% of the total project costs. Using the official housing backlog together with the current budget allowance for the basic dwelling unit, the cost implication of introducing the requirements of the revised NBR is R23,736,321,000.00 (€1,682,454,168.80).

Passive design as a goal

According to the Department of Minerals and Energy (DME), houses and other buildings in South Africa are seldom designed with energy consumption or energy efficiency in mind [7]. Specific mention is made of the energy characteristics of low-cost housing. The DME indicates that low-cost housing could be rendered 'energy smart' through the utilization of elementary passive solar building design practices, resulting in fuel savings of up to 65% [7].

[2] A performance approach to specification is suggested as an alternative where the roofing material and insulation used should achieve a total minimum R-value = 3,67 m^2•K/W (or equivalently to m^2•°C/W). [7] [8]

The DME Report No. 2.34-33 titled *Energy Efficiency: Energy and Demand Efficiency for Commercial Buildings* identifies passive solar design criteria for commercial buildings [8]. Among others, these include Orientation, Overhangs and shading, Insulation, Windows, Thermal mass, Layout and configuration as well as Day lighting.

Using cost as selection criteria, it is evident that specific items, from the aforementioned list, are applicable to the low-cost residential sector of South Africa. The above aspects in isolation will not be able to address existing (and future) energy consumption in the built environment. It is argued that the expansion of the aspects, as listed in Table 2 below, could contribute to a more sustainable built environment, whilst limiting additional costs.

Table 2: Refining the exiting NBR passive design criteria

Passive design requirements with no building cost implication
1. Orientation • The functional aspects of building design in warm climates (with particular reference to thermal and ventilation considerations) was studied extensively by the National Building Research Institute, at the Council for Scientific and Industrial Research in Pretoria. According to van Straaten, in South Africa, "[t]rue north/south orientation… is generally considered best for all buildings … because the windows can then be protected almost completely by relatively simple fixed exterior shading devices in the form of horizontal projections." [9] The majority of habitable rooms should face North, or within 14˚ East of North, or within 14˚ West of North. [9]
2. Natural light (This existing regulation is currently not being implemented; see Part O of the NBR [10]) • Each habitable room should have a total window area of at least 10% of the floor area (or 0,2 m²) for natural lighting [11], as required in the existing editions of SANS 10400.
3. Ventilation (This existing regulation is currently not being implemented; see Part O of the NBR [10]) • Each habitable room should be naturally ventilated, using openable windows of at least 5% of the floor area (or 0,2 m²) for ventilation [11] , as required in the existing editions of SANS 10400. • The design (on plan and section) should integrate cross ventilation, corresponding with the dominant wind direction for the area. [9]
Passive design requirements with limited building cost implication
4. Shading of openings in northern walls: Exposed glass surfaces • Exposed glass surfaces in north-facing walls should have a protective roof overhang and/or shading device (i.e. shutters, screens or trees). [9]
Passive design requirements with building cost implication
5. Storm water harvesting • Against a global rainfall average of 962.7 mm per year, South Africa receives a mean annual precipitation of 500 mm, making it the world's 30th driest country. The introduction of gravity fed rainwater-harvesting systems with storage tanks could utilize this scarce resource.

Conclusion

Despite different opinions regarding the extent of the current housing shortage, the largest part of the South African population relies on government subsided housing. This represents the biggest spatial need in the South African built environment. The scale of the housing need exacerbates the cost implication of introducing new sustainability measures. The unique socio-economic circumstances in South Africa and the prevalent climatic conditions warrants a different view to limiting energy consumption in the South African built environment. Current planning and construction practices for low cost housing do not take cognizance of passive environmental design. Presently, low cost housing is exempted from the NBR, and the existing edition of the NBR does not include pertinent passive design measurements. Further studies into these aspects should be conducted to limit environmental impact, reduce operating costs while providing a more habitable built environment.

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Adapting Building Regulatory Systems to Better Address Climate Change Impacts

Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee

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Brian MEACHAM, Fire Protection Engineering and Architectural Engineering, Worcester Polytechnic Institute, Worcester, MA, USA (bmeacham@wpi.edu) – *Adapting Building Regulatory Systems to Better Address Climate Change Impacts* (session moderator)

Abstract: *The contribution of the buildings sector to climate change is significant and widely acknowledged [1]. At the same time, buildings are vulnerable to the effects of climate change, including drought, wildland fire, flooding, snow loads, storm (wind) intensity and more. While these issues have been studied to various extents, the building regulatory systems, within which buildings are effectively designed and operated, have received almost no attention. To complicate the situation further, the building regulations and codes themselves have not holistically considered how changes in materials and systems meant to decrease carbon emissions might actually be increasing building vulnerability. These challenges are amplified in building regulatory systems where measures of performance are unclear, responsibility for design, approval and enforcement is diversified, and no single entity has an understanding of the holistic building performance. Given the convergence of these factors, strong consideration must be given to restructuring of building regulatory systems to better understand and address holistic building performance in the face of climate change adaptations, physical impacts resulting from climate change effects, multiple and potentially competing policy directives, government resource limitations, and an increasing reliance on self-control via market mechanisms. If the system as a whole is not adequately considered, history has shown there can be opportunities for significant regulatory system failures [2-5].*

Keywords: *Building Regulatory System; Performance-Based Building Regulation; Climate Change*

1. The Problem

Building regulatory systems are complex systems of systems. They typically include some type of legislative mandate for building regulation and control, a building code, which includes regulatory requirements for the design and construction of a building, reference standards which address testing, installation and maintenance, and some type of building control. They may include reference to code of practice for designers and others, created by professional organizations. Minimum competency requirements for practitioners, and mechanisms to assess and license those practitioners, may be included as well. In some cases, market-based mechanisms, such as ‘private certification,’ ‘self-regulation,’ or third-party market controls, as might be set by the insurance industry, may exist as well. While complex, the system has worked generally well when focused on issues of occupant health and safety. Increasingly, however, building regulatory systems are becoming complicated by policy mandates originating from outside of the historical realm of building regulation, including environmental and resource legislation (energy, water, material), which are in some cases imposing ‘competing objectives’ and difficult enforcement challenges. This includes energy performance legislation leading to measures which create fire safety challenges, and planning/zoning legislation which can create fire safety challenges (densely grouped buildings, small roadways) and in some cases the construction of buildings in at-risk locations (prone to flooding, sea-level rise, etc.). Such challenges are also seen with market-based, voluntary approaches aimed at increasing energy performance of buildings, such as BREEAM, LEED, and others. Such approaches are developed completely outside of the building regulatory system, and their implementation is often targeted at existing buildings, for which building regulatory oversight is typically less than with new construction.

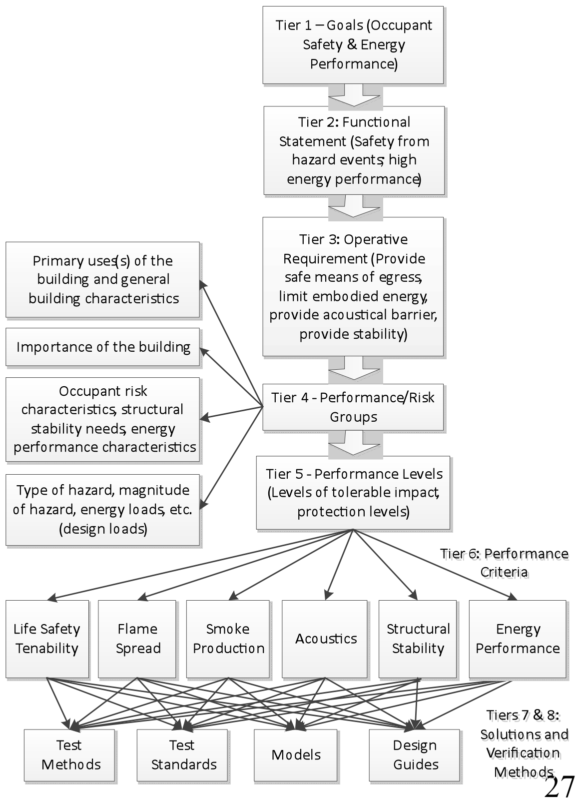
As a result, while the number of governmental policies and market approaches aimed at increasing the sustainability of the built environment developed in recent years is considerable, their success in facilitating a sustainable built environment has arguably been limited [6]. The stakeholders in the construction and building regulatory markets are fragmented and not working effectively together [1,6], inconsistent levels of performance is being realized through voluntary measures [7.8], there are incomplete building performance measures, monitoring and enforcement mechanisms [6,9] and increasing liability concerns [10]. The fragmented regulatory approach and introduction of competing objectives has led to unintended consequences being introduced, some of which present considerable risk to building occupants. The push for new technologies for energy efficiency and performance in building is introducing a wide range of hazards, including structural hazards due to moisture-related failures of enclosed structural systems [2-5], health hazards related to mold and indoor air-quality due to weather-tight buildings [11], fire and health hazards due to the flammability of thermal insulating materials [12-14], fire and smoke spread potential through the use of double-skinned façades [15], and fire hazards and impediments to emergency responders associated with interior and exterior use of vegetation (shading, green roofs, etc.), among others [14]. The ‘competing objectives’ between sustainability and fire safety are particularly complex due to the multidimensional aspects of each. For example, timber is ‘sustainable’ but also is combustible, so if not addressed appropriately can present a significant fire safety hazard [14]. High strength concrete requires less material and is more sustainable than regular strength concrete, but can be highly susceptible to spalling during a fire if not modified [16]. These ‘competing objectives’ can result in significant performance challenges for buildings.

2. What Can Be Done?

In part, the fragmented approach to building regulatory development and control, and the resulting competing objectives and creation of potentially hazardous conditions associated with the noble goal of becoming more sustainable, can be related to the lack of a broadly agreed framework for holistically describing and assessing building performance across all societal objectives. Buildings, like building regulatory systems, are a complex system of systems. To function properly, all aspects must be in sync. This is difficult to control if there is no framework within which to test the system. This situation can become exacerbated with deregulation and downsizing of government control if there is not clear guidance to the private sector entities who take on responsibility for the holistic performance of buildings. To address these issues, change is needed across the whole of the building regulatory system, including policy formulation, structure of regulations, and means of 'checks and balances' within the system. In some countries, change to the building regulatory development process may be needed. In all cases, a more robust building regulatory framework will be beneficial. In all cases, more explicit identification, acceptance and control of risk needed. In addition, more data, tools and methods are needed relative to the holistic performance of buildings across all required attributes. That is, instead of focusing primarily on one attribute for a specific policy objective or solution (e.g., thermal performance for an energy efficiency objective), the focus needs to be on adequately characterizing the performance across all essential areas (e.g., thermal performance, fire performance, health effect, etc.) and developing processes, tools and methods to assess influences of one objective on another. Finally, building regulatory systems need to do a better job of addressing existing buildings. While issues associated with safety performance have been known for decades (e.g., large life-loss events lead to building code changes, in some cases retrospectively), the extent of issues associated with climate change (e.g., energy performance) and resilience to impacts of climate change (e.g., higher strength storms, coastal and other flooding concerns, etc.) have only started to be a focus. The situation is complicated by voluntary measures in some areas, such as energy performance rating schemes resulting in building changes which reduce safety.

3. Starting Point: The IRCC Performance-Based Building Regulatory Framework

Based initially on a structure outlined by the Nordic Building Codes Committee (NKB) in the late 1970s, a model for performance-based building regulations has been suggested by the Inter-jursidictional Regulatory Collaboration Committee (IRCC) [17-19]. Illustrated in Fig. 1, the model assumes that regulatory provisions are based on policy goals (essential interests of the authorities), and through increasing levels of detail, functional and operational requirements are described. Functional requirements provide qualitative statements about the desired function of buildings or specific building elements. Operative requirements provide a level of detail that can be applied to design and construction, ideally presented as quantitative requirements, and expressed in terms of specific performance criteria or expanded factional descriptions. Performance or risk groups aim to provide a mechanism for grouping requirements for different building uses (e.g., residential, business, assembly) based on common risk or performance targets. Performance levels define



the common targets under various conditions or events. Instead of prescribing a single set of design specifications for compliance, the approach requires that instructions or guidelines be provided which outline how compliance with the functional and operative requirements is to be verified. These instructions or guidelines can include engineering analyses, test methods, measurements and simulations. In addition, examples of acceptable solutions, deemed to satisfy the building regulations, are to be provided. Several countries are currently operating with building regulations which fit some, if not all, aspects of the model [17]. The IRCC model is attractive because it places the focus on goals and objectives for the building, and allows for a variety of mechanisms to be used to demonstrate compliance. However, the model does not provide guidelines for how to apply the process / framework to the revision of existing building regulations, or to development of new regulatory requirements and supporting components, such as for sustainability and climate change. In particular, gaps exist in guiding users as to how to best identify and incoporate a suitably broad and informed set of stakeholders for identifying appropriate performance and risk levels, in understanding and applying suitable decision-making processes in the performance and risk criteria setting process, and connection of quantified design criteria to performance expectations. These areas are critical in advancing the applicability of the model for addressing new and emerging issues, such as climate change impacts on building.

4. Where Do We Go From Here?

To move forward, several steps are needed. First, there needs to be a shift in thinking from viewing buildings as a collection of independent systems, to viewing buildings – and building regulatory systems – as complex systems of systems with strong interrelationships between subsystems and overall building performance. Increasing energy performance should not be considered without assessing impacts to structural performance, indoor air quality, fire performance or other attributes. Reducing material should not just be viewed as a cost savings or sustainability measure, but resulting structural performance, fire performance and related factors need to be considered. Viewing the problem as being a complex systems problem is not new [e.g., 5, 20], but thus far a true shift in thinking has not occurred, and the 'silo' based approach is creating new hazards and risks as it tries to mitigate others.

Second, a broader set of stakeholders is required to feed into the regulatory development and control process to help assure the key societal and policy objectives are met. Experience within the countries participating in the IRCC shows that building regulations are largely formulated by a small group of specialists, be they codes- and standards-making committees, bureaucrats, consultants or some combination [17]. These experts may consult other experts for specific issues, when deemed appropriate, and they may also consult the public. However, given the relatively small numbers of experts involved, it is questionable if the process results in a broad enough discussion of critical issues – technical, political or societal. This has been observed by others in the area of sustainable design and construction as well [e.g., 20-22].

Third, in addition to breaking down the 'silo' based approach and broadening the stakeholder participation in the building regulatory process, governments need to find ways to likewise break down the silos between departments and agencies responsible for the various parts of the problem, and get the right participation from each organization together in the regulatory policy-setting stage. It is impossible to control the changing nature of political agendas. However, the translation of political agendas and policy directives into regulation is largely a function of civil servants, and much more coordination can occur at the upper levels of governmental departments and agencies.

Fourth, while the IRCC model provides a good starting point, advancements are needed in several key areas. Again, these are unfortunately not new, having been identified at least ten years ago [19]. Methods need to be developed to help identify emerging hazards and threats, the likelihood of the hazards or threats occurring, the potential consequences, public expectations with respect to protection, available mitigation technology, cost, and deciding who will pay. Assuming societal expectations can be identified, and performance goals developed, tools, mechanisms and criteria that are necessary to define, measure, calculate, estimate, and predict performance must be developed. To make sure holistic performance is achieved, more research is needed to characterize and define the linkages and interrelationship between goals, objectives, criteria, test methods, and design tools and methods. The right balance of regulatory and market mechanisms are needed for optimization of the system. While some new thinking in risk-informed performance-based regulatory and design structures have been explored [e.g., 23,24], and tools for assessing the interrelationships of performance objectives have been outlined [24], considerably more advances are needed.

Fifth, government needs to recognize that one of the biggest challenges with energy policy, resilience to climate change, and health and safety of occupants in buildings is how to achieve objectives in these areas within existing buildings. In most countries the building regulations do not address existing buildings, except when significant renovation or change of use occurs. To truly make advances in energy, resiliency and safety performance across the built environment, building regulatory systems need to address existing buildings. While this is being done in some areas, like the Energy Performance of Buildings Regulation (EPBR), the silo-based approach (i.e., considering energy but not safety) runs the risk of creating the types of unintended consequences identified above (e.g., fire, health or structural safety hazards).

Finally, in order to address the wide range of issues, a new process for building regulation development would be beneficial. It is suggested that the approach utilize an analytic-deliberative process to identify the pertinent issues, obtain needed data and information regarding holistic building performance, and facilitate decisions amongst the range of actors involved. An approach such as proposed for the development of risk-informed performance-based building regulations [25], coupled with advancements on the IRCC Hierarchy (Fig.1), would seem to serve this purpose well.

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