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Abstract

Energy consumption in Gulf Cooperation Council (GCC) countries has been rising over the last four decades. The residential building sector alone accounts for more than 50% of all delivered energy consumption, and half of this is attributed to the use of air conditioning for cooling. Better building design, triggered by stricter building regulations, could drive down this energy use considerably. In this work, the authors have reviewed, evaluated, and compared the current building-energy regulations in the Gulf Region, as applied to residential tall buildings. The goal was to understand and discuss the major challenges, opportunities, and novel approaches being developed and deployed.

Keywords: BuildingCode, Energy Efficiency, Façade

Introduction

While holding approximately 30% of the world's proven oil reserves and 22% of the world's proven gas reserves (BP 2016), the energy demand in the six countries of the Gulf Cooperation Council (GCC), consisting of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE), has been increasing sharply in the last decades. This is driven by a rapidly growing population and the huge diversification plans, massive industrialization, and construction projects that aim to pull the economy away from oil dependency. Perhaps ironically, this has resulted in more energy-intensive developments, which in turn require more fossil-fuel consumption. As a result, the GCC countries are among the top 25 countries for CO_2 emissions per capita, according to the United Nations Statistic Division (2007) and the Climate Analysis Indicators Tool (CAIT), which stresses the need for ecological modernization and environmental improvements (Lahn et al. 2013).

This rapid development in the Gulf Region is also strongly associated with tall building construction, which plays a crucial role in emphasizing the role of global placemaking and international tourism within the growing cities of the GCC countries, typified by the race to construct the world's tallest building – first the Burj Khalifa in the UAE, and now the Jeddah Tower in Saudi Arabia. While this high-density construction typology can be regarded as a necessity in the hot desert climate of the region in order to avoid sprawl and reduce energy and efficiency losses (Hammoud 2016), the availability of cheap energy has created a significant number of tall buildings characterized by fully glazed façades, which are implemented without consideration of cultural context nor in compliance with fundamental energy efficiency rules (Meir et al. 2012).

The Economic and Energy Context

Since the discovery of oil in the region in the 1930s, GCC countries have relied on oil for national and energy security. The exploitation of vast oil reservoirs in the area in the second half of the 20th century has led to unprecedented modernization and industrialization at both urban and rural levels. This rapid development caused a sudden growth in population and produced a significant rise in national income, which in turn created a great demand for housing. As a result, the decisions regarding the urban and built environment were made under increasing pressure, with no time for an evolutionary process for planning or design concepts. At the same time, this new architecture was enabled by plentiful air conditioning and economical mass production, replacing the more climatically and

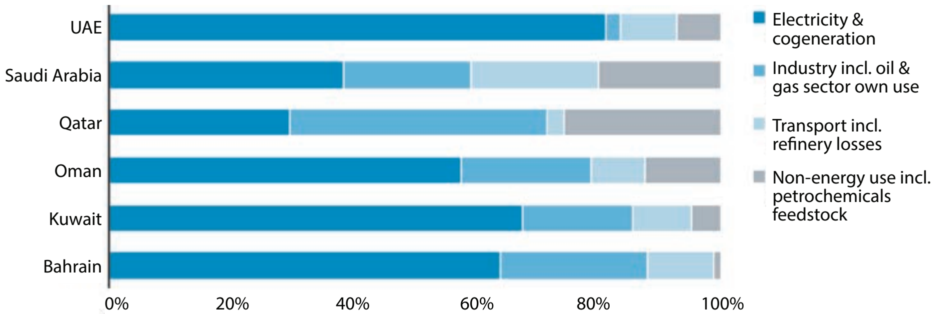

Figure 1. Simplified sectorial breakdown of the energy resources consumption in the GCC countries in 2010. Source: Lahn et al. (2013)

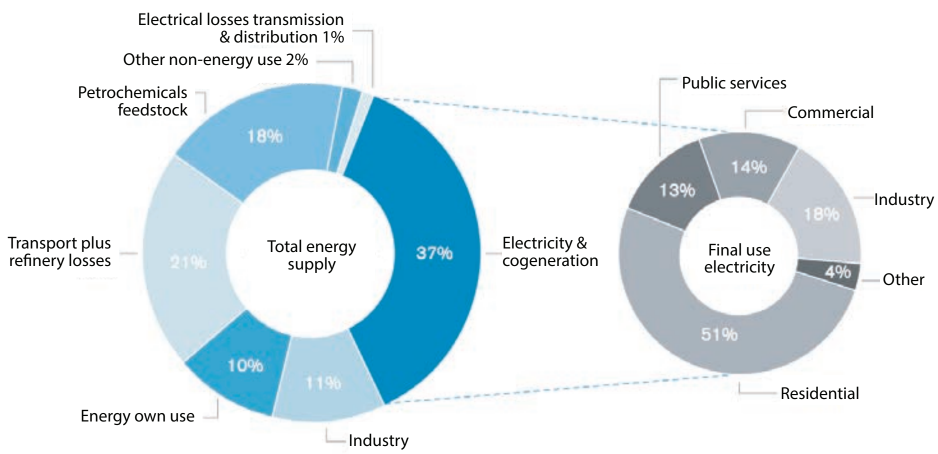

Figure 2. The total energy supply breakdown for Saudi Arabia, illustrating how 51% of the final electricity use is consumed in the residential sector. Source: Lahn et al. (2013).

culturally appropriate vernacular architecture. This was followed by the economic growth of the late 1990s and early 2000s that led to megascale projects and tower architecture, in line with the diversification plans that aimed to reduce reliance on oil-based income (Bahaj et al. 2008). This active construction, most evident in Dubai and Abu Dhabi in the UAE and Doha in Qatar, has occurred at a frantic pace, with no time to study or realize the implications on the environment. Accordingly, the issue of sustainability has been neglected. Consequently, in 2011, the GCC countries consumed almost as much oil and gas as Indonesia and Japan combined, and more than the entire continent of Africa, yet they have just 5% of Africa's population, and this high energy consumption has been rising inevitably and is expected to nearly triple by 2030, with Saudi Arabia being the largest contributor due to the country's much greater population and land size, which requires serious energy-efficiency policy interventions (Lahn et al. 2013).

To inform the appropriate design interventions, it is important to examine the energy uses in each country. Figure 1, shows a simplified sectorial breakdown of energy consumption in each GCC country, representing the four main segments: electricity and cogeneration, industry, transport, and non-energy use. The breakdown illustrates how electricity generation losses, mainly used for air-conditioning and water production, represent a high portion of energy consumption (Alnaser & Alnaser 2011, Lahn et al. 2013).

Focusing on energy consumption patterns, Figure 2 illustrates that 37% of the total energy consumption in Saudi Arabia is due to electricity and cogeneration, and 51% of this primary energy is consumed in the residential sector. This clarifies that housing and residential buildings are responsible for more than half of all delivered energy consumption across the country, with air conditioning comprising a disproportionate share. Cooling accounts for more than 70% of electricity consumption in the residential sector in Saudi Arabia and about 40% of the total annual electricity consumption (RCREEE 2015). This identifies buildings, especially residential, as a key area for improvement in energy efficiency, affecting the local economies in the region, as reducing the domestic use of fossil fuels would mean more exported oil and natural gas, besides the obvious local environmental benefits.

Following those lines, the global rise in sustainability awareness began to take hold amongst decision makers and developers in the GCC countries since 2009. Remarkable progress is evident in relation to clean energy targets and efficiency strategies that emphasize the sustainable energy transition, reflecting the governments' growing concern about domestic energy consumption (Lahn et al. 2013). Improving building efficiency is the one area where GCC countries have agreed to introduce a cooperative plan and are making progress on establishing a common buildings standard, taking into account the common climate and sociocultural factors. Pilot studies and practices show that adapting the built environment and building codes to work with, rather than against, the Gulf Region's harsh climate represents some of the largest proven savings in the GCC to date, with up to 60% reductions in energy demand due to changes to existing buildings, and 70% in new buildings, against the existing average (RCREEE 2015). However, these scattered conservation efforts have been largely ineffective, due to factors such as bureaucracy and governance challenges, lack of awareness, information, enforcement, and market incentives, as well as unpredictable political support. As such, it is essential to have collaboration between ministries, municipal governments, and electricity authorities to strengthen the enforcement of these common building standards.

Housing and Tall Buildings In the Gulf Region

Although the vast fossil fuel reserves in the GCC Countries resulted in a rapid economic growth, it is the desire to diversify from oil that has driven the recent unprecedented boom in real-estate development (Hammoud 2016). In addition to the urban population growth, the concentration of economic, industrial, and administrative activities that have increasingly attracted large domestic and foreign populations (Al-Shihri 2016), have resulted in a booming expansion in the construction sector in GCC countries. With up to five million residential units under construction, it is among the biggest and fastest-growing construction markets in the world. This rapid development is also strongly associated with global placemaking and international tourism, in which tall building construction has played a crucial role, leading to the race to create the world's tallest building as a mechanism for generating value and identity (Hammoud 2016).

Looking at the history of tall buildings in the Gulf Region, observational analysis reveals three or four historical phases related to the economic booms in the region, where the design of the building façade is the most distinguished changing element (see Figure 3). The earliest tall buildings were constructed between the early 1970s and the early 1990s, during a sustained oil boom. In this first generation of buildings, a solid, punched window façade design was dominant, which can be considered an advantage in the hot climate of the Gulf Region cities.

The second phase of tall buildings was in the second half of the 1990s and early 2000s, corresponding with the diversification plans in the GCC countries, as many of the major cities in the region tried to reinvent themselves as major international and modern destinations with a corporate-style management. This led to megascale projects, especially in the UAE. The tall building construction was very rapid, and the façade designs ranged from semi-transparent or partially-glazed façades to fully-glazed façades, which were globally criticized as being energy-hungry and relying completely on extensive mechanical air conditioning, which itself is dependent on low-cost, fossil-fuel-derived electricity (Elkadi 2006).

The current, third phase of tall buildings represents the global awareness toward sustainability and energy efficiency in architecture. New tall buildings that claimed to be "green," "environmentally-friendly," and climatically responsive have emerged. The façade design seems to be the main controlling environmental strategy in these buildings, either through advanced shading systems, orientation, and responsive transparency, opacity in the glazed façades, or through double-skin façade technologies.

Because the tall building typology was introduced in many cities in the Gulf Region as an attempt to boost tourism, hotels and residential towers dominate the tall-building market in the region (Bahaj et al. 2008). For example, in Dubai, which contains most of the tall buildings in the Middle East, 52% of tall buildings over 150 meters' height are residential. By adding the 31 mixed-use towers that include residential floors, about 70% of the tall buildings over 150 meters carry a residential profile (CTBUH Skyscraper Center 2017).

As for Jeddah, Saudi Arabia, 56% of the tall buildings are residential or include residential floors, and there is an increased demand for high-rise residential apartments, especially along the Corniche overlooking the long distance views to the city to the south and east, and the Red Sea to the west (Hammoud 2016) These buildings demonstrate a varying range of success in terms of balancing the market requirements for views and for protecting their façades from intense sunlight (see Figures 4–7). Though most of the tall buildings in the region are residential, very few studies have been conducted regarding the environmental performance of this building type, which emphasizes the importance of evaluating how this building type responds to the challenging hot climate of the Gulf Region.

Energy-Efficient Building Regulation In the Gulf Region

Adapting the building codes and regulations to the local climate of any region represents some of the largest proven savings and reductions in energy demand. Nevertheless, amongst the GCC countries, the most progressive energy efficient building regulations are in the UAE and Qatar, which have developed exclusive building codes to address the problems of sustainability and standardization to bring building construction on par with international standards. The Estidama Pearl Building Rating System (PBRS) in Abu Dhabi, which began to be applied in 2010, was the first of its kind in the Gulf Region to draw on international best practice, but with adaptations to local climatic conditions and social needs. Qatar has pioneered the Global Sustainability Assessment System (GSAS), in which energy and water efficiency are also benchmarked and attached to a six-star rating system. And while Saudi Arabia has been quick to follow, Bahrain and Oman have yet to assertively

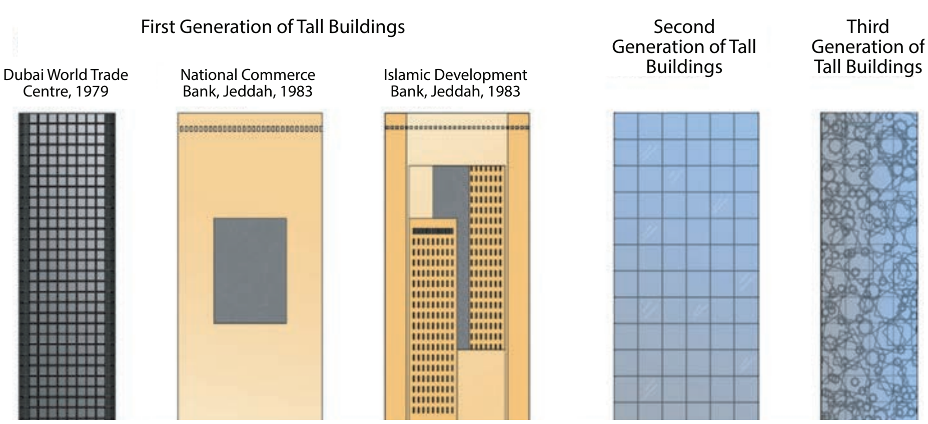

Figure 3. Three generations of tall buildings in the Gulf Region. Note the more solid façade design in the first generation, while the second generation proposed full transparency. The third generation combines glazing and shading technologies in façade design.

pursue green building construction. Moreover, as mentioned earlier, the GCC countries have agreed to introduce a common standard for energy-efficient regulations, which considers the existing standards through close cooperation between the standards authorities of each country, and is likely to draw heavily on GSAS and PBRS (Lahn et al. 2013).

Dubai: Green Building Regulations and Specifications (GBRS)

The government of the UAE has concentrated on improving the building sector as a major consumer of energy in the country and realized the important role that efficiency codes play in reducing high energy consumption. In Dubai, the Electricity and Water Authority issued the second phase of its GBRS in April 2010, based on a "regulatory framework" instead of a "rating system," which reviews various aspects of the building process and gives "credits" or "points" towards an award for a certain level of achievement. The GBRS are applied voluntarily to public and private buildings, but are mandatory for all new governmental buildings. The GBRS are Dubai-specific, closely related to local climate and conditions. The aim of the regulations is to create a link between Dubai's building regulations and the wider picture of sustainability. They propose to improve buildings' performance by reducing the consumption of energy, water, and materials; improving public health, safety, and general welfare; in addition to enhancing the planning, design, construction, and operation of buildings.

The main advantages of the GBRS are that they are accessible and available online, and that they have the flexibility to propose both the prescriptive, elemental method, and the simulation-based performance method. They provide clear communication to designers, architects, developers, and contractors, in terms of explaining the reasons and benefits for each regulation, its impact on sustainability, the environment, energy efficiency, and user comfort. Ultimately, although extremely tall buildings are exempt from these regulations, and they are not specific to residential tall building design, the regulations can be applicable to most building types, covering many aspects for sustainable building design, explaining in clear and direct language the intentions and benefits behind applying them, in addition to some technical data and specifications to guide the parties involved in building construction (Dubai Municipality 2011).

Abu Dhabi: Pearl Building Rating System (PBRS)

The government of Abu Dhabi launched the Estidama Program as part of the *Plan Abu Dhabi 2030* urban master plan that addresses sustainability as a core principle (Abu Dhabi UPC 2010). The PBRS is one of Estidama's key initiatives, which is similar to other Leadership in Energy and Environmental Design (LEED)- and Building Research Establishment Environmental Assessment Method (BREEAM)-inspired assessment tools, but is very detailed and multi-faceted, and is expected to be integrated into the local building code (Meir et al. 2012). The PBRS aims to address the sustainability of a given development throughout its lifecycle, from design through construction to operation, providing design guidance and detailed requirements for rating a project's potential performance in relation to the four pillars of Estidama: environment, economics, culture, and social. The rating system consists of two types of credits: "required" credits that must be met by every project submitting for a Pearl Rating, with no credit points awarded for achieving them; and "optional" credits, which are voluntary performance credits, from which points may be accrued.

Depending on the Pearl Rating level being pursued by a design and development team, the number of credits and the level of achievement will vary from project to project. To achieve a one pearl rating, all the mandatory credit requirements must be met. Starting in September 2010, all new buildings were required to meet the one pearl requirements, while all government-funded buildings were required to achieve a minimum of two pearls (Abu Dhabi UPC 2010). Similar to Dubai's GBRS, the documents for the PBRS are accessible and

Figure 4. Al Jawhara Tower, Jeddah.

Figure 5. Corniche Dreams, Jeddah.

Figure 6. Masarat Tower, Jeddah.

Figure 7. The Headquarter Business Centre, Jeddah. © Batley Partners International

> “SBC601 states that buildings with a height of four or more stories above ground are considered ‘commercial buildings,’ regardless of the number of floors that are classified as residential. Thus, all tall buildings, regardless of their function, are classed as commercial buildings.”

available online, and even though they are a ranking system, they do set minimum mandatory performance requirements for all building types in Abu Dhabi, including multi-residential developments. This combines the advantages of enforcing the requirements while offering the flexibility of optional improved standards. The PBRS requirements also endorse both prescriptive and performance methodologies for building codes and regulations. However, unlike Dubai GBRS, the energy requirements in PBRS are not specific to Abu Dhabi, since they follow American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standards, and do not set specific energy performance targets.

Qatar: Global Sustainability Assessment (GSAS)

In 2013, The Gulf Organization for Research and Development introduced the GSAS framework, formerly known as the Qatar Sustainability Assessment System. The assessment system was developed by drawing best practices adopted from 40 different rating systems known regionally and internationally to create a sustainable built environment that minimizes ecological impact while addressing specific regional, environmental, cultural and political needs (GORD 2017). The measurements for the rating system are designed to be performance-based and quantifiable, customized to the unique conditions and requirements of Qatar (Meir et al. 2012). It was incorporated into Qatar Construction Standards 2010, and it is now mandatory for all private- and public-sector projects to get GSAS certification (Zafar 2017).

GSAS includes schemes and typologies to evaluate commercial, core and shell buildings, residential (single-family housing units, multi-unit dwellings, and high-rise condominiums), education buildings, mosques, hotels, light industry, and sports facilities, as well as projects on the scale of parks and districts. The criteria of GSAS are divided into eight categories: urban connectivity, site, energy, water, material, indoor environment, culture and economic value, management, and operation. These categories are broken down into specific criteria with associated quantifiable measurements that define individual issues used to measure the project’s impact. GSAS is considered the world’s most comprehensive green building assessment system, and all its information and documents are accessible to the public. Most importantly, unlike the other local building codes and rating systems, it uses a holistic analysis for the predicted building energy consumption and sets targets for energy performance, which also covers the assessment of residential tall buildings in the region. This led to GSAS being revamped and repositioned to be adopted by other GCC countries as a regional green building code.

The Saudi Building Code Energy Conservation Requirements (SBC601)

The Saudi Building Code (SBC) was set up based on the International Code Council (ICC) and published in 2007. It includes SBC601, which is based on the International Energy Conservation Code (IECC). The SBC601 established minimum prescriptive and performance-related regulations for the design of energy-efficient buildings through the design of building envelopes and the selection and installation of energy-efficient mechanical, service water heating, electrical distribution, illumination systems, and equipment for the effective use of energy in buildings (SBCNC 2007). They consider two building types: residential buildings (detached one- and two-family dwellings and townhouses) and commercial buildings. SBC601 states that buildings with a height of four or more stories above ground are considered “commercial buildings,” regardless of the number of floors that are classified as residential. Thus, all tall buildings, regardless of their function, are classed as commercial buildings. The approach is identified by an “acceptable practice,” which specifies the criteria for the building envelope components, based on the percentage of the walls’ glazing area, that should be used for compliance assessment. However, the functional and environmental requirements for commercial and residential building types are different in terms of users’ occupancy patterns, affecting internal heat gains and thermal and visual comfort requirements. Hence, applying the same building envelope requirements to different building types is questionable.

At the same time, the municipality of Jeddah has been exploring the idea of setting guidelines for the design of tall buildings since 2007, especially after the announcement that the 1,000-meter-plus Jeddah Tower would be built there. In 2013, the final Guidelines for Tall Buildings Specifications and Technical Requirements were proposed, which aim to develop an integrated and well-connected urban fabric, creating a distinctive skyline for Jeddah. The aim is to generate an attractive environment via tall buildings that include active and successful open public spaces and pedestrian zones, while reducing the influence of tall buildings on surrounding spaces in terms of services, traffic movement, and environmental impact.

Document	Compliance approach	Implementation	Engineering parameters	Design parameters	Energy performance targets	Notes
SBC 601 (Saudi Arabia)	Prescriptive & Performance	Mandatory	SHGC and U-value for windows U-value for opaque elements based on glazing ratio & CDD	None	None	Reference to the ASHRAE Standards 90.1-2007 for the engineering parameters
GBRS (Dubai)	Prescriptive & Performance	Mandatory to governmental buildings; voluntary public and private buildings	SC, VLT, and U-value for windows U-value for opaque elements based on glazing ratio	Considerations for external shading devices	None	Specific to Dubai's climatic conditions and needs
PBRS (Abu Dhabi)	Performance	Minimum requirements are mandatory for all buildings; additional requirements for governmental buildings.	Considered in the Building Performance Rating Method outlined in Appendix G in the ASHRAE Standards 90.1-2007	Considered as additional credit points (not mandatory); design measured mentioned included (orientation, glazing ratio, external shading)	A minimum 12% performance improvement compared to the baseline building performance as per the ASHRAE Standards 90.1	They provide a prescriptive approach but not relevant for tall buildings
GSAS (Qatar)	Performance	Mandatory for all private and public sector projects to get GSAS certification	Inputs for the Energy Performance Calculators	Considered	Baseline reference for Energy Demand Performance for residential buildings = 121 $kWh/m^2/yr$	Specific to Qatar's climatic conditions and needs

Table 1. Comparison Table of local energy-efficient building regulations in the Gulf Region.

Comparison and Discussion

The four local energy-efficient building regulations in the Gulf Region were reviewed for evaluation and comparison. Table 1 summarizes the main findings in relation to compliance approach, implementation status, engineering and design parameters, and energy-performance targets.

Generally, mandatory energy-efficiency regulations for buildings, if enforced properly, can constitute a strong driving force for the construction industry, including architects, real estate developers, and construction companies, to start integrating sustainable and energy efficient solutions in buildings. However, the local standards apply only to new buildings and are often poorly enforced. Instead, a mandatory regulatory framework focusing on all buildings should be applied, ensuring that all buildings implement sustainable practices. The responsibility for enforcement usually lies with municipalities, which often lack financial and human resources to do so. This is true especially because designing, constructing, and renovating buildings according to energy efficiency specifications requires upgrading skills, knowledge, and expertise of professionals in the building sector (Lahn et al. 2013, (RCREEE 2015).

Many cities in the Gulf Region are investing in residential tall buildings, and this new trend constitutes an architectural paradigm shift that focuses on sustainable design and represents a new generation of tall buildings, offering high-performance systems, high-quality materials, and better interiors for occupants (Al-Kodmany 2016). However, the challenge lies in applying energy-efficient building practices to more than a handful of high profile projects in the Gulf Region. This will only happen through mandatory energy-efficient building regulations and the provision of greater incentives for developers to build more sustainably. ■

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