Water–Energy Nexus

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The sustainability or green building rating system used in the United Arab Emirates (UAE), Pearl Rating System (PRS) of Estidama, similar to other international rating systems such as LEED and BREEAM, considers several strategies, regulations, and policies to improve the energy and water performance in buildings. However, the applicability of considering water as part of energy or the fact that utilization of energy mandates the usage of water seems unexplored and not yet included in any of the existing building rating systems including LEED. A unified approach of the water and energy resources is hence vital for future considerations in energy policy, planning and the inclusion of the same in the sustainability rating systems as well. This paper investigates, as a case study, the prospects of water-energy nexus in the prevailing UAE green building rating system; Pearl Rating System(PRS) to bring out if any water conservation strategy has an adverse effect on energy and vice versa. The review revealed that the major shortcomings of PRS in terms of water-energy nexus strategy are the usage of reference codes not suitable to UAE's climate and geographical conditions, inexistent synergy between some credit categories, oversight of rebound effects, and a need for credit reassessment. The paper also recommends that any proposed strategy to realign credit categories in terms of water-energy nexus with the potential risk to also have a hidden negative rebound effect which the researchers and practitioners should identify lest the water- energy tradeoff bring unprecedented repercussions. The theoretical analysis established that the bifurcating management of water and energy in the sustainability rating system and energy policy needs to be revisited in order to reap more sustainable and optimum results that is environmentally, ecologically and financially consistent. The theoretical analysis established that the bifurcating management of water and energy in the sustainability rating system and energy policy need to be reformed in order to reap more sustainable and optimum results that is environmentally, ecologically and financially consistent.

Water-Energy Nexus, Sustainability, Rating Systems   Estidama

1.Introduction

The United Arab Emirates (UAE), similar to many fast growing economies, has been indexed as one of the countries producing the highest carbon footprints in the world [1][2]. Researchers opinion that the electricity consumption has doubled in the last ten years and the main attributing factor to this surge is attributed due to rapid urbanization, population and economic growth in the country [3]. The energy consumption has been increasing at an annual rate of 4% and it has reached 5% in 2020. Statistics also reveal that the country's final electricity consumption was 127.53 terawatt-hours in 2018 [4]. Similarly, the water demand of UAE is around 550 l/day, which is thrice the water demand in Europe and US [5] and twice than that of desert regions of middle east such as Saudi Arabia, Lebanon and Egypt [6].

Most research carried out apropos of water-energy nexus is concentrated around energy production and water treatment facilities. However, the building sector consumes nearly 90% of UAE's energy, but the water-energy nexus, and its applicability is not yet considered in the built environment [7]. Green building rating systems such as LEED, BREEAM, Pearl Rating System all aims to conserve energy and water by incorporating several strategies [8][9][10]. Yet, it can be argued that the water-energy nexus approach strategies are not addressed in these rating systems or in any current energy policy. The water-energy nexus concept was introduced as many strategies that aimed to save one resource in isolation often caused a strain in the other, sometimes to the extent of creating negative rebound effects. The problem can potentially become volatile in UAE, because, though energy and water is produced in thermal co-generation plants, strategies to conserve them are conditioned to be implemented in isolation with no regard to the rebound effects that the resources could impinge on each other. Therefore, it is essential to explore if any strategies implemented from water or energy domain without synergy consideration are producing a negative rebound effect.

2. Water–Energy Nexus: Conceptualization

The water–energy nexus has been attracting global attention in the last decade, although the concept was conceived in the middle of the 20th century where the formal address of water-energy nexus was initiated by the US federal government enacting it in the Energy Policy Act 2005 under section 979 [11]. Since then, the interrelation between water and energy has been debated and discussed at various international conferences [12]. However, the lack of data availability including robust research in this area has blurred the accurate understanding of this phenomenon [13][14][15][16].

The water footprint of energy has been relatively less studied compared to the energy footprint of water [17]. Often, consideration of water as a form of energy is overlooked, but its extraction and processing require an indispensable quantity of water similar to secondary energy generation, e.g., electricity [18]. Similarly, 75% of water distribution and wastewater treatment costs are associated with electricity consumption, infamously called the energy cost [19]. Renewable energy generally broadcasts an image of green energy and conserving the environment against the exploitation of fuel extraction and processing found in the conventional energy generation systems, but in contrast to this popular belief, it has been found that some of these renewable energy systems are more water-intensive than conventional ones [16], including the carbon capture and sequestration systems by thermoelectric power plants [20].

3. Case Study : Pearl Rating System of Estidama

3.1 General Overview of Pearl Rating System

The first and most widely used rating system, Pearl Rating System (PRS) of Estidama, is a design methodology that was developed as a key product of "Abu Dhabi Vision 2030" to drive the construction industry of Abu Dhabi to green building standards. PRS is an evaluation framework that evaluates the building in the design, construction and operation phase under four pillars of social, economic, environment and cultural [21]. The certification of PRS was mandated by the Executive council of Abu Dhabi and came into effect from September 2010. The government of Abu Dhabi further strengthened this initiative by publishing a mandatory requirement that all government buildings in Abu Dhabi must have a minimum 2 Pearl rating and nongovernment buildings to have at least 1 pearl rating. The rating system applies to all building types such as schools, residence, villa, hospitals of Abu Dhabi, UAE.

Additionally, there are four more rating systems implemented in the UAE such as Al Safat (Dubai), Barjeel (Ras Al Khaimah), LEED and BREEAM, the last two being international sustainability rating systems. Al Safat and Barjeel are relatively new, and in their initial stage of implementation whereas PRS is well established. The theoretical analysis conducted for PRS is also valid for all the aforementioned rating systems including the international ones as the two resources are extremely vital in their importance. Figure 1 illustrates the different credit categories of PRS.

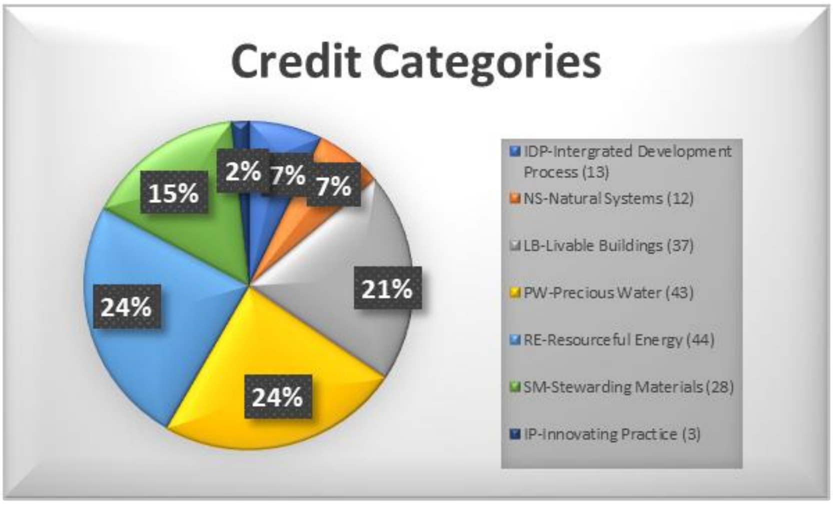

Figure 1. Credit categories of Pearl Rating System

3.2 Case study Description

This case study aims to analyze the energy and water credit categories of Pearl Rating System (PRS) from water-energy nexus perception to understand and abridge the potential benefits of synergizing the main two resources that are primarily used in the country through theoretical triangulation. Theoretical triangulation process with meta-synthesis research process has been used to dissect the rating system. Though the two resources can be constraints to each other, an integrated approach in energy policy guidelines and building rating systems is deemed necessary to understand and validate the benefits of water and energy savings. The assessment carried out for water and energy credit categories also tries to determine the concordance with other credit categories that utilize energy or water to provide a holistic solution. The technical possibilities for nexus implementation with the identified pitfalls is also briefly described.

3.3 Assessment of energy credits of Pearl Rating System

The energy section in PRS aims to reduce the consumption of energy per capita in the country as it is feared that the demand for energy will surpass its supply if the current trend remains. Buildings consume a tremendous amount of energy and release CO_2. Henceforth, PRS believes that through proper technique and strategies intended to conserve energy during building design and construction will bring significant results to curb the energy demand during the operational stage as well [21].

Table 1:Summary of the Energy category of Pearl Rating system with identified problems from nexus perspective

Category code	‘Resource Energy’ Category	PRS requirements	Identified problems	Technical Possibilities
RE-R1	Minimum energy performance	PRS focusses on performance improvements concerned with reduction in energy consumption while ignoring energy costs. Use of code ASHRAE 90.2 for energy calculations.	May provide incomprehensive methodological analysis in relation to efficiency calculations in Estidama PRS.	Modifications are need to be made in the reference codes reflecting the actual energy issues of the country
RE-2	Cool building strategies	Recommended to use vegetated roof gardens.	Native or adapted plant species will require extra water.	PV roofs are suggested as they can help to reduce the electricity demand of the building[22]. Moreover it decreases reflection to the surrounding spaces which inturn helps to reduce UHI and not create an impact on local microclimate. PCM based roofs are also promising to reduce
RE-2, LBo-R3, LBo-1	Cool building strategies, Outdoor thermal comfort strategy and Improved outdoor thermal comfort.	Recommends the use of high SRI roofing materials to reduce heat gain to the building and PRS argues this strategy will provide positive	Reflection of one building will affect the daylighting views and the energy requirements of adjacent buildings.	

		impact of local microclimate.	Increases urban heat island effect.	energy consumption[58] and for reducing heat. Composite PV-PCM is a viable option based on country's geographic, climatic regions.
RE-6	Renewable energy	To provide renewable energy to grid and the bearer to be sufficed with REC certificates. Credit awards for deep geothermal systems, landfill gas systems claiming these systems to be eco-friendly. Production of energy from waste diversion plants.	Currently UAE has not materialized REC or supplying electricity to grid. These systems have negative impacts like earthquakes& risks including release of toxic gases in case of waste incineration plants which needs to be studied. None of the above systems are established in UAE.	None of the above systems are currently established in UAE. Hence it would be best if these credits are modified to only include what's currently possible in the country. This problem can also lead to clients losing credit as they cannot pursue
IDP-LCC SM-9 to13	Life cycle costing, Stewarding materials	Credits are awarded for performing calculations. SM category emphasize huge importance on incineration plants.	LCC not linked to energy consumption. No incineration plants yet established in UAE.	Directly linking LCC with reduction of energy costs and with material category, could help the technical team to implement them mandatorily
LBo-7	Bicycle facilities	Provision of showerheads of max 10 with safety lockers and changing rooms.	Due to intense and harsh weather conditions, people use bicycles only for 3-4 months/ year making	The credit need to be reassessed in concordance with UAE's climatic conditions.

PW-4			these extra facilities redundant	

3.4 Assessment of Water credits of Pearl Rating System

Water credit category of PRS totals up to 45 points which is more than other prominent rating systems around the world and is justifiable considering the acute shortage of freshwater in the desert region. However, when water saving is linked to the energy required to produce or consume it or when synergy between several assessment credit points is critically reviewed, some of these strategies seem to echo their inherent potential loopholes as described in section below. Unlike energy, water usage is easy to identify at the consumption stage and resolution strategies easily identifiable.

Table 2: Summary of the water category of Pearl Rating System with identified problems from nexus perspective

Category code	'Precious Water' Category	PRS requirements	Identified problems	Technical Possibilities
PW-2.1	Exterior water use reduction	Credit points like PW-2.1, NS-3 and NS-4, all encourage the use of native plant species.	Not considered synergy amongst the credit categories that may cause the client not to consider them altogether	Need to consider all credit points encompassing the usage of native plant species to be grouped together, hence water requirement will be less and help in the credit accumulation savings for the client.
PW-2.2	Exterior water use reduction	8 credit points are for non-water based heat rejection system and only 2-5 for water based ones.	Research shows water-based ones are more efficient and hence larger buildings can only use them not the air based one.	Need for reassessment of distribution of credit points based on performance.
PW-4	Stormwater management	·Install appropriate systems and treat	·UAE has little precipitation, hence does	·The guideline mentioned not suited for

	90% of stormwater Reference guide is CSIRO	not justify the expensive installation of equipment which require additional energy for operation and maintenance.	UAE hot desert climate, hence its recommended to be changed. ·Since precipitation is very weak, credit points could be reduced.

4. Results and Discussion

The theoretical analysis revealed four major shortcomings existing within the Pearl Rating System. They can be mainly categorized as, usage of reference codes that are non-compliant with UAE's geography and climate conditions, non-synergy between few categories, oversight of certain rebound effects, the need for credit reassessment. The analysis ascertained that even though water-energy nexus can bring more effective energy savings, rebound effects must be considered when finalizing the optimal solution as even a solution viable from the nexus point of view may have other unforeseen ecological, economical problems. Figure 2 illustrates all the identified shortcomings with respect to water-energy nexus along with the credit categories.

Figure 2: Identified shortcomings from W-E nexus perspective

5. Recommendations to Implement Water–Energy Nexus in Pearl Rating System

5.1. Linking of Nexus in Energy Model Simulation

Currently, the PRS uses water building calculator tools and dynamic energy simulations like Equest and Integrated Environmental Solutions or in short IES for energy simulation and reduction. A few independent researchers have modified the simulation methodology to isolate the result of energy savings by water reduction and link it to savings of fuel types necessary to produce that electricity. However, these experiments are, still in the research and developmental phase [23]. Similarly if proper simulation tools can be developed to accommodate and take water quantification and hidden energy consumed by water in buildings into consideration based on the UAE's climatic and regional requirements, the use of the water–energy nexus in buildings would be pioneered. Designers and other stakeholders will also be able to see the simulated results and to predict actual saving and usage of water and energy. The idea that buildings are the investments of the future for business investors further emphasizes the usage of energy models for forecasting the costs and benefits of implementing various energy systems, their operations and maintenance, return on investment for onsite renewable systems, the purchase of RECs, and other high performance outcomes.

5.2. Rebound Effect of Renewable Energy Systems

The low carbon emission, clean energy production using renewable energy systems may seem like the optimal solution to the fossil fuel depletion problem, but there are numerous rebound effects linked to renewable energy systems that are often ignored by policy-makers and jurisdiction alike [24]. For example, solar- and wind-based renewable energy systems are the two most important ones, but the notion that 50% or 100% of energy requirements can be fulfilled by these types of systems is simply ludicrous because their efficiency is considered to be too dilute. Henceforth, to concentrate on this dilute energy would require a lot of additional energy and heavy wiring, and, moreover, these plants are mostly located far away from the urban areas that require tremendous energy and monetary expenditure to properly distribute to [25].

Nevertheless, with the depletion of conventional fossil fuels, it is important to focus and build viable renewable energy systems. However, in doing so, besides studying the benefits of such systems, it is vital to understand their compound influence on the energy and water requirements along with their impacts on the environment. Moreover, this implantation will be successful only if an optimal point is ascertained while considering all constraints associated with the installation of renewable energy systems, especially from the water–energy nexus standpoint for the PRS.

5.3. Reassessment of Credit Points Distribution

There are credit points that are apportioned for certain facilities or features that are not yet implemented in Abu Dhabi like incineration facilities (SM-14), metro or rail stations (LBo-6 public transport—given three credit points), or even RECs that are not currently provided by the UAE. This can cause problems with the technical team seeking overall points for rating credits when they are not even made available in Abu Dhabi. Similarly, several codes or regulations that are American or Australian-based will not be completely adoptable in the UAE because its climatic and geographical conditions are significantly different. Hence, there is a need for more rigorous research both from academicians and industry professionals in the built environment so that these issues can be rectified and ameliorated in the newer versions of the PRS.

6. Conclusion

The evaluation of Green Building rating system, in this case Pearl Rating System, the UAE local one, from the water energy nexus echoed potential flaws as water efficiency strategies were considered separately from that of energy efficiency. From the theoretical analysis carried in this paper, it was clear that besides water savings imposing a rebound effect on energy savings which is eventually reciprocated, the interaction between these resources seems to reflect complex connections with other credit point categories implying the need for its potential synergy inclusion while assessing it from nexus perspective. This case study paper identified four major shortcomings of PRS, namely usage of reference codes that are non-compliant with UAE's geography and climate, non-synergy, rebound effects and a need for credit reassessment. It was found that policies and legislations aimed to reduce the consumption of one resource have an unprecedented impinging effect on the other. Though the two resources can be constraints to each other, an integrated approach in energy policy guidelines and building rating systems is deemed necessary to understand and validate the benefits of water and energy savings. The key to achieving green and building energy efficiency lies in a smooth and transitioned leap, whilst considering and assessing the benefits and rebound of any energy solutions that are undertaken, and its impact on water resources rather than an abrupt one.

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