Article

Estidama and the Pearl Rating System: A Comprehensive Review and Alignment with LCA

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Abstract: Multiple sustainability standards and rating systems have been developed to draw attention to constructing sustainable buildings. The Pearl Rating System (PRS) is a mandate for all new construction projects in Abu Dhabi. Hence, it is important to understand the main components, advantages, and limitations of the PRS. The feasibility and the practical relevance of the PRS are still being studied. This paper addresses this gap and critically evaluates the PRS against some of the well-established rating systems like LEED and BREEAM. The analysis suggests that the PRS considers the cultural aspect of sustainability, in addition to the environmental, societal, and economic aspects. It was also found that most rating systems, including the PRS, have a very superficial inclusion of life cycle assessment (LCA). The paper finally concludes with other observations and outlook for a more robust implementation of the PRS.

Keywords: assessment tools; construction sustainability; green building codes; life cycle assessment (LCA); sustainability rating systems; sustainability standards

Citation: Ramani, A.; García de Soto, B. Estidama and the Pearl Rating System: A Comprehensive Review and Alignment with LCA. *Sustainability* **2021**, *13*, 5041. <https://doi.org/10.3390/su13095041>

Academic Editor: Manuel Duarte Pinheiro

Received: 7 April 2021
Accepted: 20 April 2021
Published: 30 April 2021

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1. Introduction

The idea of life cycle assessment (LCA) was initiated in the 1960s, when environmental degradation and access to resources became a concern [1]. ISO 14040:2006 describes the principles and framework for LCA. LCA is also described as a tool to evaluate potential environmental impacts and the resources utilized through the life cycle of a product, i.e., from raw material procurement, through production and use, to waste management (ISO/TC 207/SC 5, 2007). One of the earliest LCA studies was in packaging, concentrating on energy use and emissions, which impelled an extensive and chaotic development of the tool in the US and Northern Europe. The 1970s saw a silent period, but during the 1980s and 1990s, there were increasing efforts toward developing the methodology associated with LCA, leading to collaborations and interaction between universities and the scientific community. The application of LCA expanded to encompass a wide range of products and systems and was widely used in studies by both industry and governments.

The authors of [2] indicated that LCA is characterized by certain aspects that most assessment tools may not be able to address. They classify LCA characteristics in four categories: (a) LCA considers a life cycle perspective, (b) LCA consists of a wide range of environmental issues, (c) LCA is quantitative about the impacts assessed, and (d) LCA has its base on natural sciences. The authors of [2] identified some of the main strengths and limitations of LCA. For example, LCA is a comprehensive tool resulting from its life cycle perspective and its spread across various environmental concerns. However, this elaborate system may be a limitation because it is prone to simplification and generalization in modeling or assessing environmental impacts. One of the limitations identified was that LCA, alone, could not determine if a product/system was environmentally sustainable

because LCA can only suggest if the product/system is better but cannot suggest if it is good enough to lower the environmental impact sufficiently.

LCA is often represented as a tool for sustainability assessment [3]. Essentially, LCA allows for evaluating the entire life cycle of a product in terms of sustainability. The first efforts toward sustainable development in construction were made in the 1990s [4,5]. Three decades later, the construction sector is still struggling to construct sustainable buildings [6], and ongoing efforts are made toward sustainability in the construction sector. Although there are multiple definitions for sustainability, most agree that it encompasses three general elements: environment, economic, and social factors [7]. The Whole Building Design Guide (WBDG) Sustainable Committee mentions that the main objectives of sustainable design are to optimize the use of critical resources such as energy, land, water, and raw materials and inhibit degradation due to facilities and infrastructure during their life cycle. The WBDG Sustainable Committee [8] states six principles of sustainability: (a) optimize site potential, (b) optimize energy use, (c) protect and conserve water, (d) optimize building space and material use, (e) enhance indoor environment quality, and (f) optimize operational and maintenance practices. However, the definition of sustainable buildings is constantly evolving to accommodate local requirements, codes, and advancements in construction materials and technology. Various initiatives, including sustainability rating systems, sustainability assessment tools, green building codes, standards, and regulations, are developed to encourage construction sustainability. This study provides a review of Estidama, a sustainability initiative by the Abu Dhabi Urban Planning Council (AD-UPC), and its rating system (the Pearl Rating System—PRS).

The remaining of the paper is organized as follows: Section 2 summarizes studies integrating LCA and rating systems and the significance and inclusion of LCA in rating systems. Section 3 provides an overview of the PRS, including the credit categories and pearl rating levels. Section 4 reviews relevant studies that have applied the PRS and provides a summary of the findings. Section 5 details some sustainability initiatives across the world, summarizes studies that compared PRS with other initiatives and performs a detailed comparison of the PRS with two established and well-recognized rating systems. Section 6 presents other elements related to the sustainability considerations for the Estidama initiative and the PRS. Section 7 critically discusses the literature reviewed regarding the applications of the PRS, PRS vs. other sustainability initiatives, and LCA in rating systems. Lastly, Section 8 summarizes the study and provides directions for future research.

2. Life Cycle Assessment and Rating Systems

Several green building rating systems such as Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Methodology (BREEAM), and Green Globes have included life cycle assessment (LCA) requirements [9]. For example, LCA was introduced as a preliminary credit in LEED to boost environment-friendly building materials and assemblies and later expanded in the subsequent LEED versions. Authors of [9] mention that, since green building rating systems (GBRS) are still evolving, it is difficult to conduct a whole-building LCA, particularly in developing countries. Their study suggests that existing LCA methods in GBRS need to be refined.

GBRSs consider the whole building (i.e., LCA) and include the life cycle design in the integrative sustainable design. In [10], the authors state that, although many sustainability rating systems consider environmental factors, the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) focused on a detailed assessment all through the life cycle of a building as part of an effort to gain maximum environmental advantages. They also state that CASBEE is among the very few sustainability rating systems that consider the deconstruction stage, in addition to design, construction, and operation phases in the LCA. Another study by [11] mentions that the United States Green Building Council (USGBC) acknowledges that the complete integration of LCA in LEED may be

time-consuming. Hence, the USGBC chose two initial areas, such as building structure and building envelope, for LCA. In addition, the USGBC stated that usage of building materials assessed and rated by third-party authorities qualify to earn the LEED credits “Innovation in Design”.

Authors of [12] examined LCA in relation to sustainability rating systems such as BREEAM; LEED; CASBEE; Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB); a green building standard, Haute Qualité Environnementale (HQE); and a sustainability rating tool, SBTool. Their study identified credit categories in each rating system that address specific components of LCA. In [13], the authors mention that, with the introduction of LCA in LEED, certain LEED credits were given more focus than others (i.e., weighted). In addition, an LCA pilot credit for the use of environmentally friendly building materials and assemblies was incorporated. The latest LEED version includes LCA, mainly in the Materials and Resources category, with credits for reducing life cycle impacts, material reuse, whole building life assessment, environmental product declaration, and raw material sourcing and ingredients. Zuo et al. [14] had performed a critical review of green buildings from the viewpoint of the life cycle. The study highlighted the importance of the integration of the environment and economic assessments in the construction industry. Since the adoption of LCA and LCC in the construction industry is limited, the study suggests the following: (a) identifying the scope and range of an LCC/LCA, (b) identifying and addressing difficulties in the integration of these assessments, (c) the requirement for adequate and reliable data, and (d) the need for standardization in the assessments.

Other studies, such as those described below, have introduced LCA in green building certified buildings and models. The authors of [13] conducted an analysis to compare the application of the LEED rating system and an LCA on a building material (roof membrane). It was seen that the roof material that would have earned LEED points had performed poorly in every LCA impact category. A similar study by [15] investigated the effect of various building envelope solutions and materials on the environmental assessment of a whole building over the life cycle of 60, 80, and 120 years. The study conducted an LCA for different wall systems on a LEED gold-certified building. Results suggest that incorporating LCA in the LEED rating system will significantly enhance the sustainability assessment of buildings.

Al-Ghamdi [16] conducted a study to advance GBRS using LCA. An LCA was performed using three software tools on a model created using building information modeling (BIM). It was seen that LCA results differed by over 10% in the preoccupancy impact category and 17% in the occupancy impact category. The study highlights the significance of refining LCA methods for GBRS. Another study by [17] had performed an LCA on a LEED-certified building at the University of Victoria. It was observed that there was limited public data regarding LCA for building products, inadequate transparency in reporting, and varying data collection methods that hindered the complete integration of LCA in LEED. Although extensive research is headed in the direction of the importance of the inclusion of LCA in different GBRS, there still exists a significant gap in the integration of LCA with current GBRS.

Inclusion of LCA in GBRS

This section discusses the inclusion of LCA in three GBRS: LEED, BREEAM, and the Pearl Rating System (PRS). All the above rating systems have considered limited inclusion of LCA as optional credits within the rating systems. For example, there exists an optional credit called “Building life cycle impact reduction” in the “Materials and Resources” category for all LEED rating systems for different built environment types, such as new construction, core and shell, schools, etc. This credit can be achieved through one of four options, which are (a) reuse of a historic building, (b) renovation of an abandoned/blighted building, (c) reuse of building and material, and (d) whole building life cycle assessment. The maximum points that can be awarded to this credit are five points, with the exception of LEED core and shell rating type, which are six points [18].

Similarly, in BREEAM, there exists an optional credit “Mat 01 Life Cycle Impacts” in the “Materials” credit category in the rating systems for new construction (internationally and in the UK) and refurbishment and fit-out (internationally and in the UK). Like LEED, this credit can be achieved through one of the following two options: (a) project life cycle assessment and (b) elemental assessment of environmental performance information. The maximum number of points that can be awarded to this credit is six points [19]. The incorporation of LCA-related credits in the PRS is further limited, as compared to LEED and BREEAM. In PRS, there exists an optional credit called “IDP 1: Life Cycle Costing”, belonging to the “Integrated Development Process” credit category. The three rating systems, i.e., Pearl building rating system, Pearl villa rating system, and Pearl community rating system, have incorporated this optional credit with four maximum available points [20–22]. Table 1 summarizes these credits for LEED, BREEAM, and the PRS.

Table 1. Inclusion of LCA in LEED, BREEAM, and PRS.

LEED		Available Points
Project/Rating Type	(BD + C) New Construction (BD + C) Core and Shell (BD + C) Schools (BD + C) Retail (BD + C) Data Centers (BD + C) Warehouses and Distribution Centers (BD + C) Hospitality (BD + C) Health Care	5 (6 for Core and Shell)
Credit	Building Life Cycle Impact Reduction	
Credit Options	Option 1: Historic building reuse	5
	Option 2: Renovation of an abandoned or blighted building	5
	Option 3: Building and material reuse	2–4
	Option 4: Whole-building life cycle assessment	3
BREEAM		Available Points
Project/Rating Type	New Construction—International and UK Refurbishment and Fit-Out—International and UK	6
Credit	Mat 01 Life Cycle Impacts	
Credit Options	Option 1: Project life cycle assessment study	6
	Option 2: Elemental assessment of environmental performance information	4
PRS		Available Points
Project/Rating Type	Pearl Building Rating System Pearl Community Rating System Pearl Villa Rating System	4
Credit	IDP 1: Life Cycle Costing	
Credit Options	N/A	N/A

In summary, although some of the well-known GBRS have tried to incorporate credits related to LCA, there still exists an enormous scope for a more detailed and thorough integration. More importantly, it is seen that LCA is an optional credit in the three rating systems. Therefore, even if any of the projects conduct a partial LCA (i.e., a component or two of the whole LCA, such as life cycle costing or environmental assessment of a particular phase), they can still get a LEED, BREEAM, or PRS certification. For example, the PRS includes only the economic aspect of LCA, which is life cycle costing (LCC) as an optional credit. Similarly, LEED considers material reuse, building reuse, or renovation, and BREEAM considers environmental assessment as an equivalent LCA credit. Given the

simplistic representation of LCA in the GBRS, stakeholders are motivated to fulfill such a credit category without realizing the full potential of such an assessment approach to obtain the certification. Thus, researchers, industry professionals, and GBRS organizations must make efforts to incorporate the comprehensive LCA into the existing GBRS. Although it requires time, cost, and resources to perform LCA, it is expected that the long-term reaping benefits will overcome the short-term challenges.

3. Overview of the Estidama Sustainability Initiative

“Estidama” is the Arabic word for sustainability and the name of the sustainability initiative by the Abu Dhabi Urban Planning Council (AD-UPC). The Estidama program is a key aspect of the “Abu Dhabi Vision 2030” [23] to drive Abu Dhabi toward greener building standards [20]. It is inspired by the necessity to plan, design, construct, and operate sustainable structures while considering traditional, cultural, and climatic aspects of the region. The developed sustainability framework rates the performance of the built environment, taking into consideration four pillars of sustainability: environmental, social, economic, and cultural. Estidama is not a rating system, such as Building Research Establishment Environmental Assessment Methodology (BREEAM), Leadership in Energy and Environmental Design (LEED), Indian Green Building Council Rating Systems (IGBC), or the Global Sustainability Assessment System (GSAS). The rating system part of the Estidama initiative is called the Pearl Rating System.

3.1. The Pearl Rating System

The Pearl Rating System (PRS) is credit-based. Based on the rating process, up to five Pearls can be awarded for sustainability. All new buildings and villas are required to have a pearl rating of at least 1 Pearl, and all government-led buildings are required to have a pearl rating of at least 2 Pearls [24]. The rating system is individually developed for communities, villas, and buildings. It is used to evaluate sustainable building development practices in Abu Dhabi.

The PRS consists of the following seven components (Figure 1):

1. Integrated Development Process (IDP): To facilitate integration between the environmental and quality management systems throughout the life of a built environment.
2. Natural Systems (NS): To protect and support the local habitat and natural environments.
3. Livable Buildings/Communities/Villas/Spaces (LB/LC/LV/LS): To enhance the quality of indoor and outdoor spaces.
4. Precious Water (PW): To minimize water consumption, aid efficient water distribution and alternate sources.
5. Resourceful Energy (RE): To minimize energy use through renewable energy sources, design measures, energy efficiency, and control of demand.
6. Stewarding Materials (SM): To consider the entire life cycle during the selection of building materials.
7. Innovating Practice (IP): To boost innovation initiatives in building design and construction.

Figure 1. Components of the PRS.

The PRS has been developed for the design, construction, and operation phases of a construction project. At each phase, a rating is determined, which expires once the following phase starts. The Pearl Design Rating System rates the steps adopted toward satisfying credit requirements during the design stage of a project. It is only valid until the completion of the construction phase of the project. Until the project attains a Pearl Construction Rating, construction materials of a project must specify that the project is only Pearl Design-Rated. The Pearl Construction Rating System ensures that the project meets and incorporates its commitments made in the Design Rating during the actual construction. The Pearl Construction Rating demands that all construction materials of the project identify the project as Pearl Construction-Rated. Lastly, the Pearl Operational Rating rates the built-in features of the project and ensures the project is operating sustainably. The operational rating can be attained after the project is at least 80% inhabited or two years after construction completion. This process is depicted in Figure 2.

Figure 2. PRS at different phases of a construction project.

The pearl rating at each phase of the project is performed keeping in mind the type of project, i.e., a building, community, or a villa. There are PRSs for different built environments, such as for buildings (Pearl Building Rating System—PBRs), communities (Pearl Community Rating System—PCRS), villas (Pearl Villa Rating System—PVRS), and public realms (Public Realm Rating System—PRRS). For each of these Rating Systems, there exist “Required” and “Optional” credits. The “Required” credits are mandatory and must be met when a project is submitted for a pearl rating. Achieving the required points will yield one Pearl. “Optional” credits are voluntary performance credits for a project. “Credit points” are awarded to a project for meeting the “Optional” credits, which decide the overall pearl rating of the project. An example of credits for the “Natural Systems” (NS) component of the Pearl Building Rating System (PBRs) is shown in Table 2. The credits NS-R1, NS-R2, and NS-R3 are “Required” credits, also indicated by “R” in the “Max. Credit Points” column. NS-1, NS-2, NS-3, and NS-4 are “Optional” credits and are awarded a maximum of two, two, two, and six credit points, respectively.

Table 2. Credit Breakdown of “Natural Systems” (NS) [20].

NS	Credits: Natural Systems	Max. Credit Points
NS-R1	Natural Systems Assessment	R
NS-R2	Natural Systems Protection	R
NS-R3	Natural Systems Design and Management Strategy	R
NS-1	Reuse of Land	2
NS-2	Remediation of Contaminated Land	2
NS-3	Ecological Enhancement	2
NS-4	Habitat Creation and Restoration	6
Total		12

Each of the credits (irrespective of Required or Optional) detail the intent of the credit, credit requirement(s), award credit points, credit submission requirements for design or

construction, clarification of calculations (if any), and a reference standard recommended for consultation. An example of the credit NS-1: Reuse of Land is shown in Table 3.

Table 3. Credit Description for NS-1: Reuse of Land.

Intent	To help and support new developments, build on already used land and existing urban areas and preserve undisturbed land wherever possible
Credit Requirement	Show that at least 75% of the land has been previously developed (for both design and construction stages)
Award Credit Points	Maximum 2 points (for both of each, design and construction phases)
Credit Submission	Narrative of previous uses on-site (Only required for the design phase) Plan drawing of existing/previous development Calculations showing at least 75% of the new site area was previously developed
Calculations/Methodology	Previously developed land is classified as any site that is/was occupied by a permanent structure or a fixed-surface infrastructure. Does not include land occupied by parks, forestry, or agriculture.
References	N/A

The Pearl Building Rating System (PBRs) rates general buildings; office buildings; retail facilities, including shopping centers; service providers; multi-residential buildings; schools; and mixed-use facilities [20]. The Pearl Community Rating System (PCRS) is developed for projects that support a minimum permanent residential occupancy of 1000 people [21]. The Pearl Villa Rating System (PVRs) is developed for rating villas [22]. Furthermore, the Public Realm Rating System was developed for rating external spaces available to the public, such as streetscapes, pedestrian paths, parks, etc. [25]. The comparison of credit categories, required and optional credits, credits points, and optional credit weights for the four project types, i.e., buildings, communities, villas, and public realms, are summarized in Table 4. The weights for optional credits are expressed as percentages and are calculated based on the available credit points for optional credits. For example, in the IDP category of PBRs, the weight of the overall optional credits is calculated as follows: $(\text{Number of optional credit points} / \text{Total number of credit points}) \times 100$. That is, $(13/180) \times 100 = 7.22\%$.

Table 4 shows that, in PBRs and PCRS, the PW, RE, and LB/LC credit categories have maximum weights, whereas, in PVRs, the credit categories with maximum weights are PW, RE, and SM. This can be understandable because energy and water are two of the most significantly impacted and precious resources. In addition, in Section 4 (which elaborates on studies concerning with application of the PRS), it is seen that several studies have focused their research on the PW and RE credit categories. In the case of PRRS, it is seen that the NS, PW, and SM categories have maximum weights. This can also be attributed to the fact that PRRS is aimed to rate public spaces, and these categories may have a major impact considering the vast extent and usage of public spaces.

Table 4. Summary of categories, credits, optional credits points, and weights for PBRs, PCRS, PVRs, and PRRS.

	Category	Number of Credits		Optional Credit Points	Optional Credits' Weights
		Required	Optional		
PBRs	IDP	3	6	13	7.2
	NS	3	4	12	6.7
	LB	6	26	37	20.6
	PW	2	6	43	23.9
	RE	3	7	44	24.4
	SM	3	15	28	15.6
	IP	None	2	3	1.7
	Total	20	66	180	100
PCRS	IDP	3	4	10	6.3
	NS	3	5	14	8.8
	LC	5	12	35	22.0
	PW	3	5	37	23.3
	RE	3	8	42	26.4
	SM	3	8	18	11.3
	IP	None	2	3	1.9
	Total	20	44	159	100
PVRs	IDP	2	4	10	10.8
	NS	1	2	5	5.4
	LV	3	9	15	16.1
	PW	2	4	21	22.6
	RE	3	3	21	22.6
	SM	3	8	18	19.4
	IP	None	2	3	3.2
	Total	14	32	93	100
PRRS	IDP	4	3	3	13.64
	NS	3	4	4	18.18
	LS	6	2	2	9.09
	PW	3	4	4	18.18
	RE	2	2	2	9.09
	SM	6	5	5	22.73
	IP	None	2	2	9.09
	Total	24	22	22	100

3.1.1. Key Team Members

The team members involved in the pearl rating assessment include the Pearl Assessor and Pearl Qualified Professional (PQP). The Pearl Assessor is in charge of the submission of the required documents. The PQP oversees the pearl rating process during the various project stages. The PQP is required to know the demands of the PRSs, assist the rating process, and ensure the quality and authenticity of documents before submission to the authority for the assessment.

3.1.2. Pearl Rating Levels

The pearl rating for a project is assigned after assessing the credits awarded to a project. To achieve a 1-Pearl rating, all “Required” credits have to be met. For a higher pearl rating, in addition to the “Required” credits, voluntary “Optional” credits must also be met. Table 5 summarizes the pearl rating levels for PBRs, PCRS, PVRs, and PRRS.

Table 5. (a) Pearl Rating Levels: PBRS, PCRS, and PVRs. (b) Pearl Rating Levels: PRRS.

(a)			
Pearl Rating Level	Requirement		
	PBRS	PCRS	PVRs
1 Pearl	All required credits	All required credits	All required credits
2 Pearl	All required credits + 60 optional credit points	All required credits + 55 optional credit points	All required credits + 30 optional credit points
3 Pearl	All required credits + 85 optional credit points	All required credits + 75 optional credit points	All required credits + 44 optional credit points
4 Pearl	All required credits + 115 optional credit points	All required credits + 100 optional credit points	All required credits + 57 optional credit points
5 Pearl	All required credits + 140 optional credit points	All required credits + 125 optional credit points	All required credits + 70 optional credit points
(b)			
Pearl Rating Level	Requirement—PRRS		
Pearl	All required credits		
Green Pearl	All required credits + 50% of the optional credits		
Exemplar Pearl	All required credits + 75% of the optional credits + be a site of national significance		

4. Applications of the Estidama Initiative and the PRS

This section provides a summary of studies found in the literature related to the implementation of the PRS. In [26], the author states that Estidama presents a new aspect for growth, focusing on preserving environmental assets and natural resources in the Emirate of Abu Dhabi. Example case studies of the Capital District and Masdar City were presented. Madden (2015) indicates that the Capital District is an initiative of Plan Capital 2030 to be a sustainable, close-packed, mixed-used city with vibrant streets and public spaces hosting several well-connected communities, universities, hospitals, and employment sectors. The Capital District also provides excellent community and cultural facilities and is environmentally sustainable, with high energy-efficient structures, district cooling systems, and water-sensitive landscapes. Madden states that the Masdar City master plan had incorporated traditional Arabic architecture along with advanced sustainable designs. The transportation within Masdar includes a transit system called the personal rapid transit system (PRT), cycling, and walking. All energy required for Masdar City was planned to be achieved through renewable sources such as photovoltaics, waste to energy, evacuated tube collectors, and concentrated solar power. Moreover, Masdar had planned to combine passive solar strategies and building energy efficiency strategies to minimize overall CO₂ emissions. However, although Masdar City was initially planned to be highly energy-efficient and operate entirely on renewable energy, some of the preliminary goals regarding zero carbon and waste were curbed due to financial crisis and highly ambitious initial plans [27,28]. For example, Masdar City had aspired to host a community of about 50,000 but had developed only a small portion of the complex (phase 1 of Masdar City) [28]. Masdar City also moved from the “zero-carbon” goal to a “carbon-neutral” strategy. Although Masdar City has faced criticism for deviating from the original plans, the city retains a sustainable design and the hope of becoming a commendable eco-city in the future.

The authors of [29] state that implementation of the Estidama initiative in the Ras Al Khaimah city, along with the implementation in Abu Dhabi, can prove to be a valuable addition and a significant step to achieving the Abu Dhabi master plan 2030 [30]. The study presented two detailed analytical studies involving the Abu Dhabi 2030 plan and the efforts of Ras Al Khaimah to combat challenges while enhancing its sustainable development under the Estidama program. A comparative analysis of sustainability aspects such as environmental, social, and economic was conducted between the two cities. Some of the challenges for sustainable development in Ras Al Khaimah were: (a) lack of natural

resources, (b) loss of biodiversity, (c) primitive infrastructure, (d) lack of social awareness, (e) public acceptance of development practices, and (f) rapid unplanned development. One of the limitations of the study was the absence of a more focused analysis of the cities with respect to individual pillars of sustainability.

The author of [31] outlines the importance of implementing the Pearl Community Rating System to enhance the environmental sustainability of current existing modular neighborhoods. The Estidama initiative is mandatory for every new development: building, community, or villa [23]. However, Abbadi states that the PRS requirements for existing projects are not outlined. On evaluating and simulating four environmental aspects of the PRS, such as CO₂ and gas emissions, water usage, waste generation, and energy consumption, as part of a case study about a selected residential neighborhood spread over 5300 m², Abbadi deduced that the neighborhood met the expectations of planned neighborhoods targeted by the PRS but did not meet the higher standards set by the PRS. A simulated model of the neighborhood was used to analyze the impacts of environmental modifications. This study shows that existing neighborhoods may have sufficient potential to implement sustainable approaches and further shape the Abu Dhabi 2030 vision.

In [32], Nemer studied the possibility of reducing environmental impacts caused by high energy consumption in existing buildings. A case study was conducted on a building located at Ajman University of Science and Technology. A retrofitting arrangement in the building was simulated to assess the environmental performance based on the PRS that incorporates cooling building strategies, daylighting, and water use reduction appropriate in the hot, dry climate of the UAE. Simulation assessment was done using the software Integrated Environmental Solution–Virtual Environment (IES–VE). Results indicate that daylight retrofitting strategies, such as modifying the glass type or adding light shelves, did not deliver any positive results. The retrofitting approach in the cool building category, which involved installing aluminum cladding on external walls, was successful. Regarding water use, modified toilet fixtures reduced internal water storage by almost 33%.

The authors of [33] presented a design for a sustainable Emirati Fareej house with a central courtyard in Abu Dhabi following an integrated process of design and performance evaluation. The simulation was conducted using Enerwin-EC. The methodology adopted can be summarized as follows: (a) quantifying the problem, (b) building footprint, (c) designing passive systems (designed to earn the PRS credit ADM5: Innovation in Design), (d) designing the envelope, (e) landscape (designed to earn the PRS credit ADW5: Water Efficient Landscaping), and (f) systems (designed to earn the PRS credits: ADW1: Water Consumption and ADW2: Monitoring of Water Usage). It must be noted that all PRS credits are according to the 2008 version of the design guidelines/assessment method. A sequential stage-wise simulation was conducted over six stages with different retrofits/design changes to observe possible changes in energy consumption, HVAC systems, CO₂ emissions, indoor daylight, indoor air quality, and ventilation. The new attainable PRS credits at each stage were also identified. Stage 6 assessed the use of all previous retrofits. The results of the designed house indicate a 59% and a 55% reduction in the greenhouse gas emissions and the utility bill, respectively.

The study conducted by [34] analyzed the reduction in energy and water consumption after implementing PRS and compared it with Business as Usual (BAU) for three sample buildings: a villa, a multistory residential, and an office building. The villa considered for the study is a medium-sized villa with a built-up area of 5000 ft² (~465 m²). The residential building is a 16-story building with a built-up area of 135,966 ft² (~12,630 m²), and the office building is a 10-story building with a built-up area of 84,173 ft² (~7820 m²). For the energy assessment, the energy performance of the considered buildings was assessed. The energy-saving potential after applying PRS requirements was evaluated with the help of the software eQUEST. For water assessment, PRS and LEED calculation tools were used. The energy simulation and water analysis results showed a potential reduction in electricity between 31% and 38% and a potential reduction in water consumption between 22% and 36%, depending on the building type and other parameters. The study mentions

that monetary savings of about \$5.2 billion can be achieved over ten years after PRS regulations have been applied, along with a cumulative reduction of 31.4 million tons of CO₂-equivalent.

In [35], the authors assessed the Resourceful Energy (RE) credit category of the PRS of an old existing Emirati residential villa of site area 828 m² to show the high potential toward becoming PRS certified. The RE component of PRS consists of six credit codes: three “Required” and three “Optional”. The maximum number of credit points that can be attained by achieving the “Optional” credits is 21. Several retrofit strategies, such as insulation, passive cooling, and renewable energy generation, were included as part of the model created using Autodesk Revit 2017 and Sefaira plugin 2017 to achieve the optional credit points. The study suggested that about 16 credit points out of the available 21 credit points can be achieved with proposed changes on the considered Emirati villa, as per the RE category of PVRs.

Authors of [36] performed a comparative analysis of conventional energy systems, such as cooling, lighting, and water heating, on two sustainable models that designed a standard residential villa (with a building area of 397 m²) based on One Pearl and Two Pearls PRS requirements. Results show that (a) transforming a standard villa to abide by the PRS guidelines results in a life cycle cost reduction of 15% (\$62,000) for the One Pearl system and 33% (\$131,200) for the Two Pearls system; (b) the total annual saving of \$283 million and approximately 0.5 million tons of CO₂ emission can be possible if all existing villas are converted to comply with the One Pearl system, and an annual saving of \$607 million and 1.14 million tons of CO₂ emissions for the Two Pearls system, and, (c) total annual energy consumption can be decreased by 20% and 43% for One Pearl and Two Pearls systems, respectively.

A study conducted by [37] investigated the technical and economic benefits of refurbishing existing public housing villas in the UAE. Four public housing villas constructed between the 1980s and 2010s (one considered in each decade) were modeled and analyzed. The villa configurations of the villas are Ground (G), G, G + 1, and the total floor area of the villas were 114 m², 351 m², 394 m², and 472 m², respectively. The Integrated Environmental Solutions–Virtual Environment (IES–VE) energy modeling software was used to assess the energy consumption and savings resulting from the implications of various refurbishment configurations on the villas. The refurbishment configurations included upgrading three components: wall insulation, roof insulation, and replacing the glazing. The annual electricity savings showed that the most cost-efficient refurbishment was upgrading the wall insulation, which resulted in savings of up to 20.8%. The next cost-efficient strategy was the upgrade of the roof insulation, resulting in savings of up to 11.6%. Lastly, the replacement of the glazing resulted in savings of up to 3.2%. All three refurbishments, simultaneously implemented, saw savings up to 36.7% (these results were seen in one of the four villas considered for the study). The savings can also be expressed as an annual reduction of 22.6 tons of CO₂ emissions. In addition, the simple and discounted payback periods for the different configurations are between 8 and 28 and 10 and 50 years, respectively.

Authors of [38] state that the Abu Dhabi Educational Council (ADEC) had planned to construct over 100 schools with a target pearl rating of 3 Pearls. However, only 20% of the constructed schools were able to achieve the target rating. Hence, [38] assessed possibilities for better performance for one of the schools that did not achieve the target pearl rating. Three renewable energy systems, consisting of a photovoltaic array, an absorption cooling system, and a geothermal cooling system, were applied and tested for performance using the Transient Systems Simulation (TRNSYS) software. This contributed to a decrease of 19% in the yearly energy consumption and incremented the school’s performance by an additional 14 credit points, which were necessary to achieve the target pearl rating.

Some of the studies discussed are summarized in Table 6 for easy reference. It can be seen that the majority of the studies focused on villas, followed by buildings. In addition, it is seen that most studies focused on existing projects. It is also seen that the most addressed

credit categories are the Resourceful Energy (RE) category, followed by the Precious Water (PW) category.

Table 6. Summary of studies that applied the PRS.

Study	Qadir et al., 2019	Salim & Abu Dabous, 2018	Al Dakheel et al., 2018	Abu-Hijleh et al., 2017	Abbadi, 2015	Nemer, 2015	Assaf & Nour, 2015	Al-Sallal et al., 2013
Development Type	Building		✓			✓	✓	
	Community				✓			
	Villa	✓	✓	✓			✓	✓
PRS Components	IDP							
	NS				✓			
	LB/LC/LV				✓	✓		
	PW				✓	✓	✓	✓
	RE	✓	✓	✓	✓	✓	✓	✓
	SM				✓			
	IP							✓
Type of Study	Existing Project	✓	✓	✓	✓	✓	✓	
	Design Study		✓					✓

Technology Integration of the PRS

Several researchers investigated the applications of Computer-Aided Design (CAD) and Building Information Modeling (BIM) in sustainable construction [39–42]. Welland [42] states that sustainability assessment through traditional CAD models cannot be satisfactorily conducted, as rectifications can only be possible at a later stage of construction, and it would be highly expensive and time-consuming to implement corrective actions.

Hence, [43] performed a feasibility analysis to automate several stages of the rating process using Building Information Modeling (BIM). The study investigated the existing causes for delay in the PRS and suggested a novel approach to overcome the problems identified. Some of the shortcomings of the PRS are strenuous and extended human interference, manual assessment, and limited resources for a large volume of projects, which pose a risk of an inaccurate review process. A qualitative survey with construction industry professionals, including personal interviews and questionnaires, was conducted. Some of the prerequisites identified for the integration were (a) a defined contract to structure and outline the BIM parties involved and (b) willingness to adopt the change. Some of the possible areas of interaction between BIM and the PRS “Resourceful Energy” credit category proposed by [43] are (a) energy, daylight, and water usage analysis to measure the credit “Minimum energy performance (RE-R1)”; (b) energy, daylight, and solar analysis to evaluate the credit “Cool building strategies (RE-2)”; and (c) energy analysis to measure the credit “Peak load reduction (RE-5)”.

5. The PRS and Other Sustainability Initiatives

First, it must be noted that, although many studies stated the term “sustainability initiative”, the term is vague and does not convey the specifics of the initiative. Although there are many studies related to sustainability initiatives, there is no defined taxonomy or categorization of initiatives. Therefore, based on the literature reviewed, the existing sustainability initiatives are classified into rating systems, sustainability assessment tools, and codes/standards.

Based on the authors’ understanding, sustainability rating systems provide guidance or a methodology to rate a project’s sustainability performance. They are usually credit-based, or point-based systems to evaluate projects and have a defined categorization of rating levels awarded to projects. Sustainability assessment tools may refer to systems or approaches that may help evaluate specific components (e.g., energy efficiency, water

consumption) or general components of sustainability. Sustainability assessment tools may or may not have defined rating levels, such as those found in rating systems. Sustainability codes/standards may refer to guidelines to assist with the design or operations of a project or may help the project comply with the local regulations.

Sustainability rating systems, tools, and codes are continually evolving to accommodate new standards; more aspects of sustainable construction; and changes in the environment, economy, and society. Section 5.1 describes some of the widely used international rating systems and tools. Section 5.2 details some of the studies that performed a comparative analysis of the PRS and other rating systems, tools, and codes.

5.1. Technology Integration of the PRS

5.1.1. Rating Systems

This section describes some of the most common sustainability rating systems from across the world, such as Building Research Establishment Environmental Assessment Methodology (BREEAM), Leadership in Energy and Environmental Design (LEED), Green Globes, Indian Green Building Council Rating Systems (IGBC), Egyptian Green Pyramid Rating System (EGPRS), Comprehensive Assessment System for Built Environment Efficiency (CASBEE), and the Global Sustainability Assessment System (GSAS) or the Qatar Sustainability Assessment System (QSAS).

BREEAM is a rating system for the sustainability of built environments launched in the United Kingdom in 1990 by the Building Research Establishment (BRE), a founding member of the UK Green Building Council [44]. The assessment process includes identifying measurable criteria for building sustainability in several categories, such as pollution, occupant health, and energy and water consumption. Credits that are achieved are awarded points, and the number of points is multiplied with an impact factor based on the relative importance of each credit section. The evaluation levels are represented as a percentage of the total available points: 30%—Pass, 45%—Good, 55%—Very Good, 70%—Excellent, and 85%—Outstanding [45].

LEED is among the most widely used sustainability rating systems in the world. It was initiated by the United States Green Building Council (USGBC) in 1998 and is built on three sustainability components, which are People (social responsibility), Planet (environmental stewardship), and Profit (economic prosperity) [18]. LEED guidelines are developed for different kinds of projects, including Building Design and Construction (BD + C), Interior Design and Construction (ID + C), Building Operation and Maintenance (O + M), Homes, Neighborhood Development, etc. LEED rating is based on a point system across the different categories of green building strategies. The rating levels are as follows: Certified (40–49 points), Silver (50–59 points), Gold (60–79 points), and Platinum (80 or more points).

Green Globes is a sustainability rating and certification tool mainly used in the USA and Canada. The system rates new constructions, renovations, and commercial interiors for a wide range of projects, including offices, schools, residential buildings, etc. Although Green Globes was initiated in the UK in the 1980s, the Green Globes rating for existing buildings was launched by ECD Energy and Environmental Canada in 2000. Later, the rating system was adapted for the USA in 2004. Green Globes is also based on a point system, where the total available points are 1000 over the categories energy, water, resources, emissions, indoor environment, and environment management [46]. The first stage of the assessment is an online questionnaire-based approach to conduct a self-evaluation of the project. If a project achieves a minimum of 35% of the 1000 points in the online evaluation, it is eligible for a third-party evaluation on the project. Upon completing the third-party evaluation, a rating of 1–4 green globes is awarded to the project [47].

The IGBC was formed by the Confederation of Indian Industry (CII) in 2001 to create awareness on sustainable buildings, cities, and green building technologies. Rating systems have been developed for various project types, including new and existing buildings, schools, factories, townships, etc. [48]. The IGBC rating system is also a points-based credit system with mandatory and optional credits. Points are awarded for meeting credits in

the different credit categories and then multiplied by a weighting factor representing the relative importance of each credit category. An overall score is then calculated, and the project is awarded one of the four certification levels. The maximum available points are 100, and the certification levels are Certified (50–59 points), Silver (60–69 points), Gold (70–79 points), and Platinum (80–100 points).

The EGPRS was developed by the Egyptian Green Building Council (EGBC) in 2010. It is based on the LEED rating system. The assessment is performed for new and existing buildings at the design and post-construction stages. Ongoing work is taking place to include the rating system for the post-occupancy stage, as well. The different components of the EGPRS are (a) sustainable site, accessibility, and ecology; (b) energy efficiency; (c) water efficiency; (d) materials and resources; (e) indoor environmental quality; (f) management; and (g) innovation and added value. The EGPRS also follows a credit-based point system, where projects are awarded points for meeting the optional credits. The rating levels are GBRs Certified: 40–49 credits, Silver Pyramid: 50–59 credits, Gold Pyramid: 60–79 credits, and Green Pyramid: 80 credits and above [49].

CASBEE was initiated by a research committee formed in 2001 that included a collaboration of academia, industry, and national and local governments that formed the Japan Sustainable Building Consortium (JSBC). CASBEE outlines guidelines for new and existing buildings, renovations, cities, temporary construction, etc. The assessment is based on Built Environment Efficiency (BEE) and Built Environment Quality (Q) values. Different values of BEE and Q decide the ranking level of the built environment, which are: Superior (S), Very Good (A), Good (B+), Slightly Poor (B−), and Poor (C) [50].

Several other countries have focused their efforts on developing building sustainability rating systems. The QSAS was initiated in 2009 on the collaboration of the Gulf Organization for Research and Development (GORD) and the T.C. Chan Center for Building Simulation and Energy Studies at the University of Pennsylvania. QSAS consists of six certification levels [47,51]. The ARZ rating system was developed by the Lebanese Green Building Council (LGBC) to establish standards for Lebanese green buildings [52]. Al Sa'fat is a green building evaluation system issued by the Dubai Municipality for new developments in the Emirate of Dubai in 2016. It consists of four rating levels for buildings: Bronze, Silver, Gold, and Platinum. The Bronze rating is the minimum requirement, and the rest of the levels are optional [53]. Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), or the German Sustainable Building Council, developed its own sustainability certification system to assess buildings, districts, and interiors. The system is built on three aspects of sustainability: ecology, economy, and socio-cultural issues. Projects are rated Bronze, Silver, Gold, or Platinum based on a performance index [54].

There are several established sustainability rating systems in different parts of the world, each with their own advantages and disadvantages. Rating systems are a more standardized approach to assess sustainability and often help project developers get new clients based on an achieved rating. In some cases, governments also mandate obtaining a rating for new projects. However, obtaining a rating may involve several formalities and tedious procedures. The following section describes some sustainability assessment tools. These tools may be more accessible to projects and may help projects do a self-evaluation to assess sustainability.

5.1.2. Sustainability Assessment Tools

The SBTool is a building sustainability tool established by the International Initiative for a Sustainable Built Environment (iSBE). SBToolPT is one of the components of SBTool specifically developed to rate and assess the building sector in Portugal [4]. Sustainable Building Assessment Tool (SBAT) of South Africa is a sustainability initiative addressing the environmental, social, and economic pillars of sustainability [55].

SITES is a US-based online sustainability certification tool based on a point system. It has four rating levels: SITES Certified, SITES Silver, SITES Gold, and SITES Platinum [56]. Energy Star is a program managed by the U.S. Environmental Protection Agency and the

U.S. Department of Energy. ENERGY STAR Portfolio Manager® is a tool by Energy Star to assess energy efficiency and monitor water consumption. The tool estimates a 1–100 ENERGY STAR score and has established itself as a standard to evaluate a facility's energy performance [57].

5.2. Comparative Analyses of PRS and other Sustainability Initiatives

This section details the studies that performed a comparative analysis of the PRS and other sustainability rating systems, tools, and codes. The literature reviewed for this section is illustrated with the help of a Venn diagram, as shown in Figure 3. The sustainability initiatives that have been compared with the PRS are categorized into three classifications: rating systems, tools, and codes/standards/regulations.

It has to be noted that there is no classification of “sustainability initiative” in this study. As mentioned at the beginning of this section, a “sustainability initiative” could refer to a rating system, a tool, a code, a standard, or two or more of these categories. For example, “Estidama” is a sustainability initiative, and it consists of a rating system, the PRS. In addition, it is interesting to observe that, since the Estidama initiative consists of only one constituent, the PRS could explain the use of the terms Estidama and PRS interchangeably in many studies.

Figure 3. PRS at different phases of a construction project.

As seen in Figure 3, this section consists of four sub-sections based on the spread of literature. Section 5.2.1 refers to the comparative analyses of PRS and other rating systems. Section 5.2.2 elaborates studies that compared PRS with other rating systems and assessment tools, and Section 5.2.3 details studies that compared PRS with rating systems and codes. Lastly, Section 5.2.4 expands on studies that compared PRS with other rating systems, tools, and codes/standards/regulations.

5.2.1. PRS with Other Sustainability rating Systems

Awadh [51] performed a comparative, objective analysis of two international sustainability rating systems, LEED and BREEAM, and two regional sustainability rating systems, PRS and GSAS. The assessment systems considered were further analyzed for their priority and attention toward the different sustainability pillars. The study also quantitatively evaluated the credit weighting in these rating systems, focusing on the energy and water criteria. The evaluation results indicate that BREEAM, GSAS, and the PRS focus on “energy performance”, whereas LEED focuses the highest weighting on “indoor environment quality”. The study also states that achieving credits/points in energy performance and renewable energy is the most rigorous in BREEAM, while LEED is liberal with the energy

performance credits category and the PRS with the renewable energy credits. Additionally, it is most convenient to earn points for water reduction in the PRS, followed by LEED and BREEAM. However, points on interior water reduction are easier to achieve in BREEAM than in the PRS or LEED. All four assessment systems diverted maximum focus on the environmental pillar of sustainability and the least priority toward the social pillar.

Hamweyah [58] compared the rating systems LEED and the PRS. The author mentions that LEED is built on the sustainability pillars economy, environment, and social responsibility, while PRS considers the environment, economy, climate, and cultural aspects. The study also states that PRS enforces an integrative design process and requires projects to perform analyses such as energy efficiency and water planning. In addition, LEED has four rating levels, while PRS has five. The study also mentions that the PRS is a much more stringent system, with a 90% improvement of benchmark for a 5-Pearl rating, against 73% improvement for the LEED Platinum rating. However, it is unclear from their study how those values were estimated. Their study also performs a comparative analysis of the weights for the main categories of the PRS and LEED. The different categories are prioritized in LEED and PRS, as shown in Table 7. Their study mentions that, although LEED is a more flexible rating system, applying the PRS in the project has fewer chances of missing documentation, misinterpretation, and manipulation. This is possible because of the tedious certification process. The study states that the PRS provides more opportunities for corrections during the project's life cycle.

Table 7. Priorities of categories in LEED and PRS [58].

Categories	Priorities (%)	
	LEED	PRS
Site Selection	24.5	16
Water	5.5	25
Energy	33	25
Materials	13.5	16
Indoor Environment Quality	14	20
Innovation	6.5	2
Regional Priority	4	NA
Integrated Design Process	NA	7

The author of [59] mentions that construction practices are prone to using a sustainability rating system without critically assessing the different characteristics of the region and the constantly adapting sustainability pillars. This can result in wrong decisions and unnecessary investments. The study performed a qualitative analysis of the PRS versus other sustainability rating systems, such as LEED and BREEAM. Although adapted from LEED and BREEAM, the PRS has a unique and progressive approach and is noticeably local. The assessment of the post-occupancy stage of a project in the PRS shows that it does not just focus on the intent of the project but also focuses on the continued commitment of the project [60]. In [61], the authors evaluated the different scales (buildings, neighborhoods, cities) of built environments assessable by some of the most common sustainability rating systems, such as LEED, BREEAM, CASBEE, DGNB, and the PRS, and compared the assessment systems across four levels: general, category, index, and indicator. It is seen that the assessment done over different categories of scales work as separate certification systems, but there are points of overlap in the building and neighborhood systems. The study indicates that city-scale evaluation has the most differing characteristics.

Authors of [62] developed a framework to evaluate different sustainability rating systems approaches and used it to assess a few widely used sustainability rating systems for communities, such as BREEAM, CASBEE, PRS, Green Star, and LEED. The framework was developed through a subjective analysis based on the available literature on sustainability

rating systems. Results of the study state three significant inadequacies in the rating systems: (a) The systems cover equivocal interpretations of sustainability; (b) The rating systems focus on sustainable design over performance in community rating systems; and (c) The ratings are irresponsive to regional conditions of a project. Another study by [63] investigated the limitations and advantages of major sustainability rating systems in the Gulf region, such as the PRS, GSAS, and ARZ, by analyzing green building initiative feedback from industry professionals. The study also developed a theory-based framework encompassing the environmental, social, and economic aspects to advance the green building movement in the region. Authors of [10] investigated the effectiveness of different assessment criteria and the implications of these criteria on assessment results for some common sustainability rating systems, such as LEED, BREEAM, Green Star, CASBEE, and PRS. The study summarized the characteristics of these rating systems based on (a) assessment criteria, (b) building phases and types, (c) scope, (d) rating levels, (e) renewal of rating, and (f) international acceptance.

Overall, it can be argued that the PRS is a relatively more straightforward approach with less scope for manipulation and misinterpretation. However, like any other approach, PRS also suffers from limitations, such as lack of standardized definition of sustainability, limited information about guidelines for renovations, different project types, etc. In addition, the PRS is still evolving to accommodate the strengths of other established rating systems.

5.2.2. PRS with Other Sustainability rating Systems and Assessment Tools

In [47], the authors proposed an energy efficiency rating system for buildings with the help of the Analytic Hierarchy Process (AHP), which develops the weights of the proposed rating system criteria and evaluates the use of AHP to develop building energy rating systems. Energy rating criteria were identified by analyzing several international green building sustainability rating systems, such as LEED, BREEAM, Green Globes, IGBC and PRS, and the tool Energy Star. A survey was further conducted among engineering professionals in Egypt to compile their opinions on the importance of the different energy rating criteria and determine if they should be categorized as mandatory or optional to have “greener” buildings. The proposed rating criteria consisted of one mandatory credit for “Minimum energy performance” and optional credits in the decreasing order of weights for the credits “Use of Renewable Energy”, “Building Envelope Efficiency Strategies”, and “Use of Energy Efficient Appliances and Equipment”.

The authors of [4] compared different sustainability rating systems, such as BREEAM, LEED, CASBEE, PRS, and GSAS/QSAS, and the assessment tool SBToolPT based on two aspects: (a) main characteristics of the assessment tools that included a timeline to emerge, size of projects that can be assessed, national scope, international scope, and rating classification, and (b) structure of the assessment tools that consisted of sustainability dimensions, identifying criteria and indicators assessment, and rating method. The study also presented a table highlighting the range of topics in the environmental, economic, social, and cultural aspects covered by the various criteria/credits of the different assessment tools considered for comparison. It is seen that most of the rating systems and assessment tools currently have greater attention toward the environmental dimension of sustainability.

5.2.3. PRS with Other Sustainability rating Systems and Codes/Standards/Regulations

The authors of [64] modeled and simulated a single-family house (one-story villa of gross area 506 m²) with the transient systems simulation program (TRNSYS). The study investigated the consequences of using different rating systems, such as LEED and PRS, and the standard ASHRAE 90.2 to evaluate the energy performance of the house. It was seen that, when applying the PRS guidelines, a significant decrease of 61% in energy use was achieved. This might have been possible due to better insulation, windows with higher efficiency, better lighting, and better air conditioning when compared to the other building rating systems/codes. On conducting the thermal comfort analysis, it was seen that the

PRS was the most suitable rating system for residential buildings in the region's hot and humid climate. Lastly, on performing the environmental analysis, it was seen that 7 tons of CO₂ were eliminated by using the PRS guidelines.

5.2.4. PRS with Other Sustainability rating Systems, Assessment Tools and Codes/Standards/Regulations

The authors of [65] screened green building rating systems, such as LEED, BREEAM, and PRS, as well as tools, such as SBAT and Green Star, and standards, such as Haute Qualité Environnementale (HQE) and Israeli standard SI 5281. The screening for these sustainability initiatives was done based on three factors: (a) representativeness, (b) re-searchability, and (c) maturity. These factors included sub-factors, such as number of certifications, number of countries, number of versions, first release year, last update year, and update frequency. For each of the sustainability initiatives (rating systems, tools, and standards) considered, a total overall score was calculated based on the above three factors. A higher overall score was observed in the rating systems BREEAM and LEED, with an overall score of above 90 points on 100, whereas the PRS scored close to 30 points on 100.

Awadh [53] performed a comparative evaluation of the Estidama PBRs and Al Sa'fat against an international standard, ISO 21929-1:2011 and SBAT, while representing all necessary information in the form of a table. ISO 21929-1:2011 outlines a basic set of indicators to account for while developing sustainability indicators to assess the sustainability of different buildings' phases, including design, construction, operation, maintenance, and refurbishment [66]. Awadh (2018) states that the PRS can be considered a total quality assessment (TQA) point-based system, where projects are awarded points for meeting the optional credits in different categories. Al Sa'fat is also a TQA system with four rating levels, which might prove to be less flexible than a points-based system in the PRS [67]. The study states that Al Sa'fat has a higher weight for energy efficiency, while PRS gives equal priority to energy and water categories. On the contrary, building vitality (equivalent to the livable buildings: indoor category of PRS) is given a higher priority in Al Sa'fat than in PRS.

In [67], the authors performed a comparative analysis of the LEED and BREEAM rating systems with some of the rating systems in the Middle East, such as PRS; Jordan Green Building Guide (JGBG); a rating tool for green buildings called Saba; and a green building initiative, Dubai Green Building Guide and Regulations by the Dubai Municipality. The study compared the rating systems and tools based on (a) vision and structure, (b) categories and weights, (c) certification levels, and (d) certification process. The study results indicate that all rating systems have the highest weight in the energy efficiency category, except for the Saba rating tool. In addition, the study suggests that, although LEED is an internationally accepted rating system, it is not entirely suited to assess projects in the Middle East, and the PRS and Dubai Green Building Regulations are more suited, considering the conditions in the region.

Another study by [68] conducted a literature-based evaluation for construction-specific parameters in sustainable design and rating systems, such as LEED, SITES, BREEAM, PRS, and the Dubai Green Building Regulations. The study states that all these assessment systems have limited focus on construction practices, resulting in sustainable designs being delivered using unsustainable construction practices. According to the authors, unsustainable construction practices contribute to a significant amount of emissions.

Table 8 provides a summary of the studies reviewed in Section 5. A significant number of studies have evaluated the PRS against LEED and BREEAM. Some of these studies performed a literature-based evaluation to compare PRS with other sustainability initiatives. Other studies assessed the initiatives based on a limited number of credit categories, rating levels, and maturity of the initiatives. Some studies had limited details about the assumptions and calculations made when comparing the weights of each category in the rating systems compared. The next section details a comparative evaluation of the PRS, LEED, and BREEAM based on different criteria, such as certification types, project types, credit categories, credits/points, rating levels, and enforcement.

Table 8. Summary of studies that compared PRS with other Sustainability Initiatives.

[illegible]

5.3. Evaluation of PRS, LEED, and BREEAM

This section presents a comparative analysis of the PRS with the two most popular rating systems, LEED and BREEAM. All three rating systems have different classifications to cover ratings for all kinds of buildings, project types, and different project stages. For example, LEED has different certification types for Building Design and Construction (BD + C), Interior Design and Construction (ID + C), Building Operations and Maintenance (O + M), Neighborhood Development (ND), Homes, and Cities and Communities. In addition, each of these certification types has certain building types covered in its scope for which the sustainability rating can be obtained. For example, the BD + C rating can be done for (a) new construction, (b) core and shell, (c) schools, (d) retail, (e) hospitality, (f) data centers, (g) warehouses and distribution centers, and (h) healthcare. Table 9 shows the comparison of the three rating systems considering aspects such as certification types, project types/scope of projects, rating levels, categories, enforcement, number of projects, etc. All the data presented in Tables 9 and 10 were collected from [18,20–22,25,45].

It was observed that LEED is a more comprehensive rating system that developed categories and credits specific for a variety of projects, such as schools, retail, data centers, etc., within multiple certification types, such as BD + C, ID + C, and O&M. The level of a detailed breakdown of project types is particularly helpful because the categories and credits developed are unique and suited to each project type. For example, in the BD + C certification, there exists a credit category called “Location and Transportation”. This credit category is allotted 16 points in the “New construction” project type. The same credit category is allotted only 9 points in the “Healthcare” project type. In addition, it is interesting to observe that LEED has a separate certification for O&M. Although LEED O&M is voluntary, projects can be rated to show their continued commitment to the sustainability certification obtained during design and construction. LEED also offers “Recertification”, which is available to all occupied and in-use projects that attained LEED BD + C and ID + C certification. The project, which is recertified, attains a LEED O + M certification. LEED Zero is another certification offered by LEED for projects that aspire to achieve net-zero carbon or other resources such as water, energy, and waste. The PRS, on the other hand, is in the process of developing guidelines for operational rating.

BREEAM also has several certification types, such as communities, infrastructure, and new construction, for several projects, such as mixed-use developments, civil engineering infrastructure, commercial projects, and healthcare. In the case of BREEAM, there is a standardized set of categories and credits for all of the project types within a certification type, with the exception of a few credit points being allotted/deducted in some projects. In the PRS, there exist four types of certifications, which include PBRS, PCRS, PVRs, and PRRS. Each of these certifications rates only a specific set of project types. For example, PBRS only rates different kinds of buildings, including general, office, retail, schools, multifamily residential developments, etc. As in BREEAM, the PRS also has a standardized set of categories and credits for different project types, with minor differences in the number of credits in each category for different projects. However, there exists some ambiguity in classifying different project types in PRS. For example, a two-story building could be a multifamily residential unit or a villa. There is no clear definition of a “villa” in the documentation of the PRS.

Regarding rating levels, LEED has four levels: Certified, Silver, Gold, and Platinum. Every fulfilled credit attains credit points, and the ranges of these levels (based on the total number of credit points achieved) depend on the certification type. BREEAM has five rating levels: Pass, Good, Very Good, Excellent, and Outstanding. BREEAM In-Use certification has an additional “Acceptable” rating level before “Pass”. In PRS, PBRS, PCRS, and PVRs have five levels, consisting of 1–5 Pearls, where 1 Pearl is the lowest rating level, and 5 Pearls is the highest rating level. In PRRS, there exist three levels, namely Pearl, Green Pearl, and Exemplary Pearl.

It is also observed that most of the categories are shared among the three rating systems. However, some are not present in the three rating systems. For example, BREEAM

has a category called “Management”, which is not directly included in LEED or PRS. Similarly, the PRS and LEED have optional credits in the category “Integrated Process”, which is not directly present in BREEAM. LEED and BREEAM have categories for “Transport”, whereas it is not a direct category in the PRS. The PRS has specific components of the category “Transport” incorporated in livable outdoor/spaces. LEED also has a separate category for “Sustainable Cities”, and BREEAM has a separate category for “Pollution”.

The enforcement of the rating systems LEED and BREEAM is voluntary, whereas the PRS is a mandate for all new establishments in the emirate of Abu Dhabi. Based on the number of certifications, BREEAM has certified over 590,000 projects, and PRS has certified over 11,300 projects. It is also seen that LEED is the most internationally known rating system, followed by BREEAM. The PRS is relatively new and still evolving. Currently, the PRS is a widely used rating system in Abu Dhabi, UAE.

Table 10 summarizes the comparison of weights for each category in the three rating systems. However, since all the three rating systems have different weights for the categories in different project types, this study has chosen to compare the categories and credits in PBRS, LEED BD + C New Construction, and BREEAM New Construction. It is observed that all three rating systems focused maximum weight on the “Energy” category. This is understandable because, in the three countries where this rating system has been developed, the primary energy sources are petroleum, natural gas, and coal [69–71]. Hence, it is crucial to conserve and protect these resources. In LEED, the next highest weight is focused on “Location and Transportation” and “Indoor Environment Quality”. These categories include credits relating to green vehicles, access around the surrounding area, bicycle facilities, air quality, thermal comfort, daylight, and so on. BREEAM focuses its next highest weights on “Management” and “Health and Wellbeing”. These categories include credits related to project plan, responsible construction practices, commissioning, indoor air quality, visual and thermal comfort, acoustic performance, and healthy surroundings. The PRS focuses significant weight on “Precious Water” and “Livable Buildings”. The “Precious Water” category is specifically important because the UAE has limited natural water resources [72]. In addition, most of the water used widely for domestic consumption is desalinated seawater. Desalination consumes a lot of energy, and hence, it is essential to find a sustainable way to utilize water in the region. The “Livable Buildings” category focuses on credits related to both outdoor and indoor spaces, such as outdoor thermal comfort, public transport, light pollution, parking spaces, smoke control, material emissions, daylight, indoor noise pollution, and so on.

Table 9. PRS vs. LEED and BREEAM.

	Certification Type	LEED	Project Type	Certification Type	BREEAM	Project Type	Certification Type	PRS	Project Type
Rating Systems	Building Design + Construction (BD + C)	New Construction Core and Shell Schools Retail Data Centers Warehouses and Distribution Centers Hospitality Healthcare	Communities—Masterplanning	Moderate to large mixed-use development Small scale project, single-use developments (e.g., Business parks, housing estates)	Pearl Building Rating System: Design and Construction	General Office Retail Multi-residential ISchool Mixed-use			
	Interior Design + Construction (ID+C)	Commercial Interiors Retail Hospitality	Infrastructure: Civil Engineering and Public Realm	Civil engineering Infrastructure Landscaping Public realm projects (Eg. Railways, tunneling, bridges) Commercial (Offices, Industrial, Retail) Public (Education, Healthcare, prison, Law Court)	Pearl Community Rating System: Design and Construction	Development projects hosting a minimum of 1000 residents			
	Operations + Maintenance (O&M):	Existing Buildings Existing Interiors Schools Retail Data Centers Hospitality Warehouses and Distribution Centers	New Construction —Homes and Commercial Buildings	Residential and non-residential institutions Data Centers Assembly, leisure, and other	Pearl Villa Rating System: Design and Construction	Villas			
	Residential	Homes Multifamily Lowrise Multifamily Midrise	In-Use—Commercial Buildings	Commercial assets Residential assets	Public Realm Rating System	Public open spaces such as streetscapes, pedestrian and cyclist paths, transit hubs, gateways, parks, gardens, waterfronts, natural features, landmarks, squares, plazas, and building interfaces.			
	Neighborhood Development	Plan Built Project	Refurbishment and Fit-Out—Homes and Commercial Buildings	Commercial (Offices, Industrial, Retail) Residential accommodation Hotels/short term accommodation					
	Cities and Communities	New cities and communities Existing cities and communities LEED Zero Recertification							
Rating levels		Certified Silver Gold Platinum	Acceptable (In BREEAM In-Use only) Pass Good Very Good Excellent Outstanding		For PBRS, PCRS and PVRS, 1 Pearl 2 Pearl 3 Pearl 4 Pearl 5 Pearl For PRRS, Pearl Green Pearl Exemplary Pearl				
Categories		Integrative Process Location and Transportation Sustainable Cities Water Efficiency Energy and Atmosphere Materials and Resources Indoor Environment Quality Innovation and Regional Priority	Energy Health and Well Being Innovation Land use Materials Management Pollution Transport Waste Water		Integrated Development process (IDP) Natural Systems(NS) Liveable Buildings/Communities/Villas (LB/LC/LV) Precious Water(PW) Resourceful Energy(RE) Stewarding materials(SM) Innovating Practice (IP)				
Enforcement		Voluntary		Voluntary		Mandatory			
Certificates		NA		592,025		11,311			
Registered Buildings/Projects		80,000 (In 2016)		2,310,418		NA			
Countries		162 (In 2016)		87		NA			

Table 10. Comparison of category weights in PRS, LEED, and BREEAM.

	Category	Number of Credits		Optional Credit Points	Optional Credits Weights (%)
		Required	Optional		
LEED BD+C (NC)	Integrative Process	None	1	1	0.9
	Location and Transportation	None	8	16	14.5
	Sustainable Sites	1	6	10	9.1
	Water Efficiency	3	4	11	10.0
	Energy and Atmosphere	4	7	33	30.0
	Materials and Resources	2	5	13	11.8
	Indoor Environmental Quality	2	9	16	14.5
	Innovation	None	2	6	5.5
	Regional Priority	None	4	4	3.6
	Total	12	46	110	100
BREEAM (NC)	Management	NA	NA	21	14.5
	Health and Wellbeing	NA	NA	20	13.8
	Energy	NA	NA	31	21.4
	Transport	NA	NA	12	8.3
	Water	NA	NA	9	6.2
	Materials	NA	NA	14	9.7
	Waste	NA	NA	11	7.6
	Land Use and Ecology	NA	NA	13	9.0
	Pollution	NA	NA	12	8.3
	Innovation	NA	NA	2	1.4
	Total	NA	NA	145	100
PBRS	Integrated Development Process	3	6	13	7.2
	Natural Systems	3	4	12	6.7
	Livable Buildings	6	26	37	20.6
	Precious Water	2	6	43	23.9
	Resourceful Energy	3	7	44	24.4
	Stewarding Materials	3	15	28	15.6
	Innovating Practice	None	2	3	1.7
	Total	20	66	180	100

6. Potential Considerations of the Estidama Initiative and the PRS

In addition to the different elements of Estidama and the components of the PRS, the following elements should be considered.

6.1. Health and Safety Aspects

Health and safety (H&S) play a significant role in construction sustainability [73–75]. Sustainable development does mean not only prudent use of natural resources but also human resources. The authors of [76] assessed the potential for implementing the PRS guidelines while considering construction workers' H&S. They conducted an extensive literature review and interviews with construction professionals in the UAE to develop a mandatory H&S requirement category in the existing PRS. Their study mentions that a more accurate analysis of H&S could enhance the overall performance and that greater visibility and transparency must be ensured, with the ability to retain and preserve valid information. They also state that there exists an oversight of H&S aspects in the PRS. Initiatives like Estidama are not usually comprehensive and can be challenged. It is suggested that higher degree enforcement must be made to enhance the H&S performance of construction. Due to several sources and discrepancies of H&S laws in the Emirate, integrating H&S with the PRS can also serve as a stable, uniform platform to implement H&S guidelines. Some of the possible benefits of the H&S integration with the PRS could result in (a) more inclusive understanding of green buildings, (b) workers being highlighted as among the most essential resources to achieve sustainability, and (c) reduction in the number of construction activity accidents/incidents [76].

Some studies suggest that green building projects and sustainable developments pose a higher risk of threat to the H&S of workers [77,78]. It can be said that the PRS ensures building and occupant safety by making cautious choices in the planning and design phase itself.

6.2. Socio-Political Aspects

Although initiatives such as Estidama aspire to achieve a higher state of environmental, social, cultural, and economic sustainability, [79] argues that the origin of eco-cities is based on strong utopianism that may have major socio-ecological setbacks. Sargent [80] defined utopianism as a state of social dreaming and envisioning of a perfect world with highly desirable facilities for a place and its residents. The author of [79] mentions that there could be adverse effects on ecology and the economy with an increasing number of ambitious large-scale sustainability initiatives.

Cugurullo [79] also stated that the concept of sustainability is not well defined in Estidama. He also indicated that it does not specify what an ideal society and its main characteristics are, what is considered a low environmental impact, and what an eco-city is. The study questions if sustainability is the real motive of such an initiative or if there is an ulterior motive. The study describes how the vision of an ideal sustainable city is used to make the capital attractive, enhance the local economy, and ensure political stability.

It is evident that the PRS is still limited on the aspects of health and safety. Although there exist stringent standards on health and safety in construction in the region, incorporating these aspects in the PRS is necessary but missing. Even though the real intent of PRS was to attain an ideal of sustainability, based on the current state of implementation and availability of documentation, it seems that PRS is still a far-fetched utopia. It might take additional effort and time before the PRS can evolve and become an established rating system.

7. Discussion and Recommendations

Sustainability initiatives across the world differ significantly in many aspects, such as climate conditions, geographical factors, resources, local policies and regulations, and cultural and social perceptions. This is probably why an internationally accepted tool to assess and rate projects worldwide, considering local conditions, has not been developed. Hence, every region developed rating systems/tools by identifying relevant categories, defining assessment criteria, and establishing assessment methods. The different rating systems developed considerably address and respond to the regional conditions of projects. Projects must critically assess the different characteristics of the region and sustainability pillars before selecting a particular rating system/tool for assessment. In addition, such levels of variance in rating systems and tools also give rise to a probable ambiguous understanding of sustainability across sustainability initiatives. It is also noticed that sustainability rating systems highly focus on sustainable designs without adequate focus on sustainable construction. This could lead to the delivery of sustainable designs through unsustainable long-term construction practices.

In this section, general observations about the studies presented in the previous sections are summarized. Significant aspects, such as contributions, limitations, research gaps, and potential future research directions, are discussed. This section is divided into three sub-sections: Section 7.1 discusses the literature relating to the applications of the PRS (Section 4). Section 7.2 discusses the PRS and other sustainability initiatives (Section 5). Lastly, Section 7.3 discusses the literature on life cycle assessment and rating systems (Section 2).

7.1. Applications to RRS

The majority of the studies focused on implementing PRS guidelines on villas, followed by buildings. However, limited attention was received for PRS implementation in communities. Regarding the PRS components (credit categories), it was observed that the Resourceful Energy (RE) category was addressed by most of the studies, followed by the Precious Water (PW) categories. This can be explained by the significant weight allotted to the RE and PW credit categories in the PRS and the broad scope available for sustainability enhancement opportunities in the RE and PW categories. The other categories that have been addressed were Livable Buildings/Livable Communities/Livable Villas (LB/LC/LV),

Natural Systems (NS), and Stewarding Materials (SM). The last two received very little attention. It is interesting to note that, although the PW and the RE credit categories are allotted the same weight in PVRs and approximately the same weight in PBRS, a lesser number of studies chose to address the PW category in villas and buildings, as compared to the RE category. It is also seen that most of the studies focused on applying the PRS guidelines to existing projects rather than use PRS guidelines to design new projects. This could be potentially attributed to the ease of implementation and investigation of PRS guidelines.

Lastly, all the studies evaluated the implications of PRS components either through simulation or through modeling with empirical analysis. A significant number of studies performed simulation analyses using software, such as IES-VE [81], TRNSYS [82], City-CAD [83], Enerwin-EC [84], and eQUEST [85]. Other studies modeled the projects using software such as Autodesk Revit and then performed an empirical analysis to apply the PRS guidelines. Given the nature of these studies, validation is one of the challenging aspects. Hence, applying the results of these studies to actual built environments may have varying implications. Further research could focus on bridging the gap between the model-predicted results and the actual values. Following such an approach, future studies could also identify the factors affecting this gap.

7.2. PRS and Other Sustainability Initiatives

A large number of studies reviewed in Section 5 focused on comparing the PRS with other sustainability rating systems. Among them, a significant number of studies evaluated the PRS with LEED and BREEAM. Few studies also evaluated the PRS with other local rating systems, such as QSAS, JGBG, and ARZ. In addition, some studies evaluated the PRS against other sustainability assessment tools, standards, and regulations. The following paragraphs critically evaluate the PRS and other sustainability initiatives based on the studies reviewed.

The PRS is among the later developed rating systems, as compared to LEED and BREEAM. It is interesting to note that, although BREEAM is the oldest rating system developed, LEED is a more internationally accepted rating system. Most rating systems around the world, including the PRS, were developed by adapting LEED and BREEAM. Although every rating system has its advantages and limitations, the PRS is a relatively new rating system that is still evolving and has much potential for improvement. The documentation and accessibility of PRS guidelines need to be significantly improved. Even though PRS is a mandate for all new projects in Abu Dhabi, there still exists uncertainty in the adaptation of guidelines. In addition, the PRS guidelines were last updated in 2010. Currently, the guidelines for the operational rating of PRS are still under development. It is of high importance to revisit and update the rating system. On the other hand, LEED and BREEAM have updated guidelines and a higher updating frequency than PRS. LEED also fares well to enforce a project to be committed to its sustainability rating by offering operational and maintenance certification and recertification. Therefore, further work on PRS should focus on improving the documentation, updating frequency, and recertification.

LEED has defined specific credit categories and credit points for several certification types and different project types. This has made the rating system quite comprehensive. BREEAM and PRS have a standardized set of categories and credit points suited for most project types in the scope of the certification, with the exception of certain project types. Taking this as an inspiration, further research efforts are warranted to investigate the expansion and incorporation of different project and certification types. Regarding the sustainability pillars considered, most rating systems consider the environment, social and economic pillars. However, the PRS also considers the local and regional aspects, which make it unique and distinct. It is also observed that the PRS captures the cultural aspects of the region, unlike in other international rating systems. Although LEED, BREEAM, and the PRS considered sustainability pillars, such as the economy, environment, social responsibility, climate, and culture, most of these systems diverted maximum focus

on the environmental pillar of sustainability and least priority toward the social pillar. Thus, further improvements to the PRS are also required to enhance the social aspects of sustainability.

LEED, BREEAM, CASBEE, and Green Star rating systems consider a higher range of building types/project types than the PRS. For example, LEED considers building types such as offices, homes, neighborhoods, developments, retail, healthcare, and schools and has a unique set of credit points for each project type. The PRS considers building types such as offices, retail, multi-residential, and schools. Future work needs to consider and expand the current categories to include all project types, apart from the currently existing limited set mentioned above. A significant difference of the PRS, when compared to others, is that it considers the assessment during the different phases of the project, including the post-occupancy stage. However, the guidelines for the operational rating of PRS are still under development.

Rating systems such as LEED, BREEAM, GSAS, and the PRS give more importance to the “energy performance” category. It is also observed that, compared to LEED, PRS has higher weights for some of the credit categories, such as water, materials, indoor environment quality, and integrated process design. On the other hand, LEED focuses on credit categories such as site selection, innovation, and regional priority. It is also seen that the PRS is the only rating system that considers water conservation as an essential credit. This can be due to the hot, arid climate of the region with less yearly rainfall. In addition, there are limited natural water resources in the region, making water a precious resource. It is also interesting to note that the PRS focuses on refrigerant-related concerns because of the higher requirement for air-conditioning systems. The PRS also prioritizes the management of outdoor amenities, natural resources, habitat, and sustainable use of land. The PRS is also among the few rating systems that consider “life cycle costing” as a credit. However, this is just a part of the LCA concept, and a detailed set of limitations and recommendations are discussed in Section 7.3.

Regarding the complexity and flexibility in rating systems, it is seen that achieving credit points in energy performance and renewable energy is most rigorous in BREEAM, as compared to LEED and PRS. LEED is liberal with the energy performance credit category, and the PRS is liberal with the renewable energy credit category. It is thus recommended to investigate the importance further and potentially strengthen this critical aspect in PRS. Additionally, studies suggest that it is convenient to earn points for water reduction in the PRS, compared to LEED and BREEAM. On the other hand, it is easier to achieve points in interior water reduction in BREEAM than in PRS or LEED. PRS enforces an integrative design process and required projects to perform analyses, such as energy efficiency and water planning. Some studies suggest that, although LEED is a more flexible rating system, applying the PRS in the project is more thorough and poses lower chances of missing documents and misinterpretation. The certification process of the PRS is tedious. Moreover, PRS provides more opportunities for corrections in the duration of the project.

7.3. Life Cycle Assessment and Rating Systems

In general, life cycle assessment (LCA) and green building rating systems (GBRS) have gained many prominences due to their direct relevance to the critical and sensitive issue of climate change. This has revolutionized the real estate market and consumer behavior. Individual consumers and government organizations are increasingly motivated toward green establishments. This has also transformed the stakeholder business model and marketing strategy to make it more appealing to the consumers. For example, consumers are willing to spend the extra money if the project has some green-related certifications or has a lower environmental impact. Therefore, stakeholders’ main goal for obtaining the certifications or conducting an LCA is to capitalize on their business model rather than assuming the full potential of the GBRS.

Comparing the implementation of LCA within the GBRS, it was found that almost all the current GBRS are an inadequate simplification of the life cycle assessment (LCA).

They do not portray an accurate representation of the sustainability and environmental implications of the entire life cycle of a construction project. LCA is predominantly a quantitative assessment of sustainability, unlike in GBRS, which has a very subjective and simplistic representation in the current form. For example, conducting an LCA is not mandated by any of the main GBRS, such as LEED, BREEAM, and PRS. In addition, not all the credit options require conducting a complete LCA of the project. Therefore, most of the stakeholders either take the easy route by obtaining the certification by conducting a partial LCA (e.g., just life cycle costing (LCC), as in PRS) or conform to an activity (e.g., material reuse) that will guarantee the credit points against the equivalent LCA credit category. Thus, it is highly likely that many stakeholders and GBRS consultants take advantage of these loopholes in the current GBRS to obtain the corresponding certifications. This paved the way for creating new roles, namely “GBRS consultants” in the construction industry.

Although the LCA inclusion in the GBRS is a great initiative, in its current form, the inclusion is not comprehensive and does not guarantee its maximum benefits. Hence, a more comprehensive and integrated approach of LCA into rating systems is necessary. That is, GBRS must advance toward developing a comprehensive set of LCA indicators and impact categories. Prior to a complete integration of LCA in building design, the relevant tools and methods must be communicated to all the stakeholders to facilitate the evaluation process. Although many studies comprehensively outlined the components and process of an LCA, it is also worth noting that it remains fragmented due to multiple available guidelines and standards. Moreover, there also exist different interpretations of these guidelines. Hence, different systems and tools adopted different techniques to conduct LCA with different boundaries. One of the other disadvantages of LCA is that it does not consider urban heat island reduction (e.g., heat reduction in the heart of the city). Due to these reasons, one must exercise extreme caution in the comprehensive LCA process integration to improve the current GBRS. This warrants for further research and case studies to get a comprehensive understanding of the financial and social implications of this integration process. To that extent, some of the recent studies in other industries emphasize the concept of life cycle sustainability assessment (LCSA), which considers aspects such as life cycle costing (economic aspect), social life cycle costing (social aspect), and life cycle assessment (environment aspect), instead of just LCA, which would cover only the environmental aspect.

8. Conclusions

This study critically evaluated the PRS against internationally recognized rating systems, such as LEED and BREEAM. Overall, it was found that the PRS is a more straightforward approach, compared to the other rating systems, with specific considerations toward the cultural aspects of the region (i.e., UAE). In addition, it was also observed that the implementation of PRS to date was mainly focused on energy, water, and comfortable (i.e., livable) buildings/communities/villas. Moving forward, it is necessary to accelerate research efforts in some of the other aspects of the PRS, such as stewarding materials and natural resources. Furthermore, the Operation and Maintenance (O&M) manual is yet to be released, and guidelines for the O&M rating are yet to be defined. Therefore, further efforts are necessary to improve the update frequency and better maintain the documentation to keep up with the recent developments in the rapidly evolving construction industry and facilitate the easier adoption of PRS.

Another major limitation of PRS is the comprehensive inclusion of LCA, which is critical but majorly lacking in many sustainability rating systems. Although some of the previous studies recommended and conducted case studies to include different aspects of LCA, a major revamp is still required to incorporate and prioritize LCA in rating systems. Furthermore, within LCA, it was observed that the focus was more on the cost and environmental impacts, and none of the rating systems include the social aspects of LCA. Future work should focus on an overall life cycle sustainability assessment (LCSA), which

is much more warranted, given the evolution of the understanding and implementation of the term “sustainability”.

Author Contributions: Conceptualization: A.R. and B.G.d.S.; Methodology: A.R. and B.G.d.S.; Research: A.R. and B.G.d.S.; Writing—original draft preparation: A.R. and B.G.d.S.; Writing—review and editing, B.G.d.S.; Supervision, B.G.d.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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