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Energy assessment and smart readiness evaluation of an educational building: A case study at Amirkabir University of Technology

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Keywords

Smart Readiness Indicator (SRI)
Energy Efficiency
Energy Consumption
Building Energy Performance
Educational Building

Article Info

DOI: 10.22060/aest.2026.25945.1010

Received date 30 May 2026

Revised date 20 June 2026

Accepted date 24 June 2026

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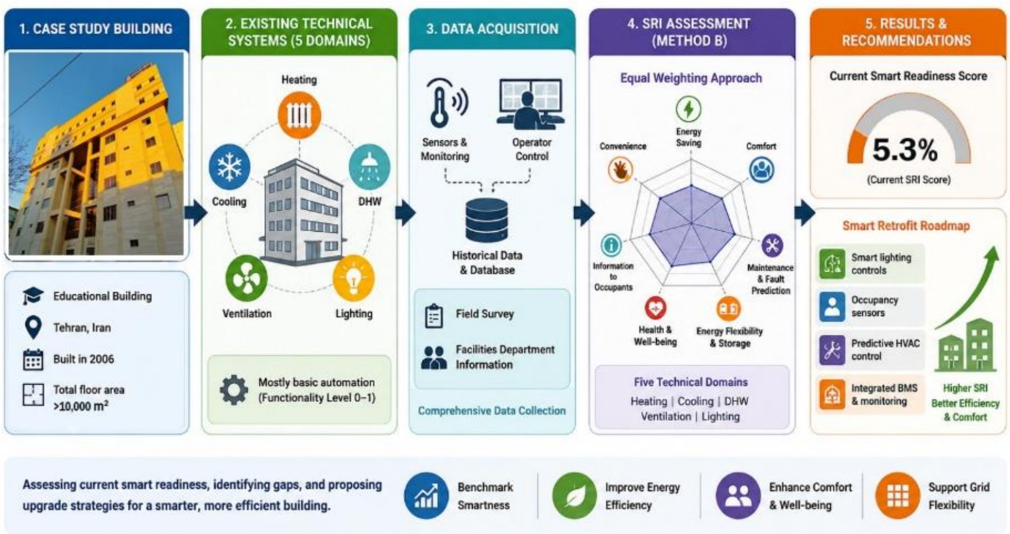
Abstract

This study evaluates the smart readiness of the two faculties at Amirkabir University of Technology using the Smart Readiness Indicator framework. To address building energy impacts, it provides a unified tool for assessing technical system functionality. Method B is applied through site inspections, interviews, and operational data. This study examines adapting the EU-based scheme to Iran, focusing on user-defined weighting. The results reveal an overall SRI score of 5.3%, indicating a low level of smart readiness in the assessed educational building. While energy-related functionalities achieved the highest performance, grid flexibility and occupant interaction remained particularly limited. The assessment identified significant opportunities for improvement through practical measures such as smart metering, occupancy-based control strategies, and enhanced building management systems. The findings contribute to the localization of SRI applications and provide guidance for future smart-retrofit strategies in higher-education buildings.

Graphical Abstract



Journal homepage: https://aest.aut.ac.ir/
E-ISSN: 3115-9117

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1. Introduction

Energy imbalance has emerged as a significant global challenge, deeply rooted in unsustainable consumption patterns and pervasive energy inefficiency across various sectors. Consequently, these issues have led to substantial energy losses and a critical decline in energy conservation efforts. Beyond these energy-related concerns, the persistence of such trends over time has severely exacerbated environmental challenges, leaving an expanding ecological footprint.

According to the Iranian Ministry of Energy, by the end of September of 2025, the number of electricity and water subscribers increased by 1.46% and 1.9%, respectively, compared with the end of the previous year. Electricity consumption was mainly attributed to the residential and industrial sectors, which accounted for 34.9% and 32.1% of the total consumption. In addition, the total volume of water produced (including both groundwater and surface water) in the urban sector decreased by 2.2% in 2025 [1]. These statistics indicate inefficiencies in energy production and consumption in Iran, which contribute to the imbalance between supply and demand.

Based on the latest data published in Iran's Energy Balance Report, a total of 49.2 billion tons of greenhouse gases were emitted, of which 72.8% consisted of carbon dioxide [2]. Within this overall profile, the building sector accounted for 36% of total CO_2 emissions and 40% of the country's total energy consumption [3]. These figures reflect the close relationship and overlap between energy consumption and greenhouse gas emissions.

Upgrading in buildings can generally be divided into two categories: renovation and retrofitting. Older buildings tend to be less efficient in terms of energy use and often require complete renovation to improve their performance. In contrast, buildings constructed more recently usually need only partial retrofitting to upgrade their current conditions. The decision between these two approaches depends on several factors, including budget, year of construction, broader urban policies, and strategic priorities. In newly constructed buildings, improvements in energy efficiency largely depend on the performance and functionality level of their technical systems. These systems provide a range of services across different parts of the building, and their functionality level can vary from basic to advanced. Higher functionality generally leads to more efficient operation, meaning that the performance of these systems directly affects both overall energy consumption and losses.

Considering the diversity of service systems within buildings, assessing the functionality level of technical systems requires an indicator capable of evaluating different types of system characteristics. In construction engineering organizations, the Energy Performance Certificate (EPC) is commonly used as a standard for evaluating building energy performance and energy usage grade. The European Commission–funded D^EPC project highlights that next-generation EPC should incorporate standardized indicators of building smartness to enable more reliable and comparable assessments, strengthen market confidence, and encourage investment in energy-efficient buildings [4].

Recently, more advanced and updated indicators have been developed. One of these is the Smart Readiness Indicator (SRI). The SRI has two advantages that are important: (a) it emphasizes the importance of smartness, mainly by means of automation and controls in a much more detailed way than EPC does; and (b) it quantifies functionality, maintainability, and, in a sense, the user-friendliness of the building, which is a critical parameter beyond energy efficiency [5].

According to Directive 2018/844, a common European framework was proposed for assessing the smart readiness of buildings through a set of indicators known as SRI [6]. The SRI is a European assessment scheme that evaluates the technological readiness of buildings to adapt their operation to the assessing the functionality levels of smart services in

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AEST
Amirkabir University of Technology

terms of energy efficiency, comfort, and flexibility. The indicator aims to increase awareness among building owners and tenants about the benefits of automation and monitoring in building technical systems. It also encourages occupants to adopt smart technologies that enhance building functionality and operational efficiency [7]. Knowing the level of smart readiness of today's buildings, it is possible to plan the changes that need to be made to move in a smarter direction.

The primary objective of studies conducted is to improve the SRI score of different building types through various scenarios, thereby contributing not only to energy consumption optimization and loss reduction, but also to the advancement of building smartness. Canale et al. [8] investigated the application of the SRI in an educational building by analysing how modifications in service systems influence both SRI scores and energy consumption. Using the official SRI calculation sheet, the study compared a Business-As-Usual scenario with an intervention scenario involving the installation of thermostatic valves on radiators. The results indicated improvements in the automation and control of the heating system and revealed a clear link between the building's energy efficiency and its smartification.

The SRI tool can be used as a benchmarking indicator to compare the smart readiness performance of buildings in different states. Apostolopoulos et al. [9] examined the application of the SRI methodology to residential buildings—Single-Family Houses and Multi-Family Houses—across five European countries in order to assess how different smart retrofit scenarios affect building smartness levels. The study applied a three-step assessment process including a baseline scenario, a retrofit scenario and an advanced scenario. Interventions such as building management systems, heating system upgrades, and ventilation with heat recovery infrastructure had the greatest impact on SRI score. The study concluded that the SRI framework is a useful tool for evaluating and promoting smart building technologies.

In another study conducted in 2024, a framework was proposed to assess the smartness and smart readiness of highly electrified buildings by Avendano et al. [10]. Two complementary assessment methods were developed: one adapted from the SRI and based on the Smart by Powerhouse scheme, which were applied to ten non-residential buildings in Norway. The results showed that the pilot buildings achieved smart readiness levels between 21.6% and 31.7%, mostly characterized by automated smartness levels. These findings indicate the possibility of integrating the SRI with other tools to assess the energy efficiency of different buildings.

Plienaitis et al. [11] investigated the application of the SRI in educational buildings to explore strategies for enhancing building smartness level, and the results revealed a strong relationship between energy efficiency and smartification. In addition, the study highlighted the importance of an SRI modification tool based on the building's location. The importance of considering multiple influencing factors when applying such an assessment tool is evident. Therefore, by referring to the study of Pompei et al. [12], the climate and regional conditions of Tehran are identified and incorporated into the analysis. The authors analyzed sustainable renovation strategies for District 5 in Tehran to improve energy performance and environmental conditions at the district level.

On a broader scale, Caracci et al. [13] conducted a statistical analysis to examine the relationship between the SRI and EPC using data from 95 non-residential buildings across 18 European countries. The results showed that SRI scores ranged from 4% to 57%, with significant differences across geographic areas and building typologies. A moderate negative correlation was found between SRI and EPC ratings, indicating that buildings with higher smart readiness tend to achieve better energy performance classes. Finally, within the next few years, after the SRI is consolidated and its weaknesses are improved, it will cease to be optional and is expected to be included in the calculation of the energy class of buildings, incorporating the result of the indicator in the energy certificate [7].

Advances in Energy Science and Technology
AEST
Amirkabir University of Technology

In this study, the technical systems and the current condition of the educational building of the Physics and Energy Engineering and Industrial Management faculties at Amirkabir University of Technology (Tehran Polytechnic) are evaluated using the SRI tool. After presenting the general characteristics of the case study building and the methodology, the selected tool is modified and applied to the building. The SRI score is then determined, and specific recommendations are proposed to improve its smart readiness level. In addition, the challenges and research gaps are discussed.

2. Materials and Methods

2.1. SRI Assessment Scheme

In order to establish the SRI methodology, three technical studies were prepared and delivered by Vito, at the request of the European Union [14]. In these studies, an assessment scheme for a brief and detailed classification of the smartness rate of buildings was developed. The Vito rating scheme assesses the following 9 domains:

- Heating;
- Cooling;
- Domestic hot water;
- Controlled ventilation;
- Lighting;
- Dynamic building envelope;
- Demand side management;
- Electric vehicle charging;
- Monitoring and control.

Each domain has specific aspects and elements which are evaluated with regard to different impact categories, and its smartness rating is delivered based on the performance of each individual component, as shown in **Fig. 1**. The assessment of smart-ready services is based on their impact on occupants, the building, and the grid, according to some distinct criteria defined by the SRI calculation methodology. In other words, the returns resulting from the services of each technical domain are classified into impact criteria. These criteria are 7 in total and are as follows:

- Energy saving;
- Maintenance and fault prediction;
- Comfort;
- Convenience;
- Information to occupants;
- Health and well-being;
- Energy flexibility and storage.

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Amirkabir University of Technology

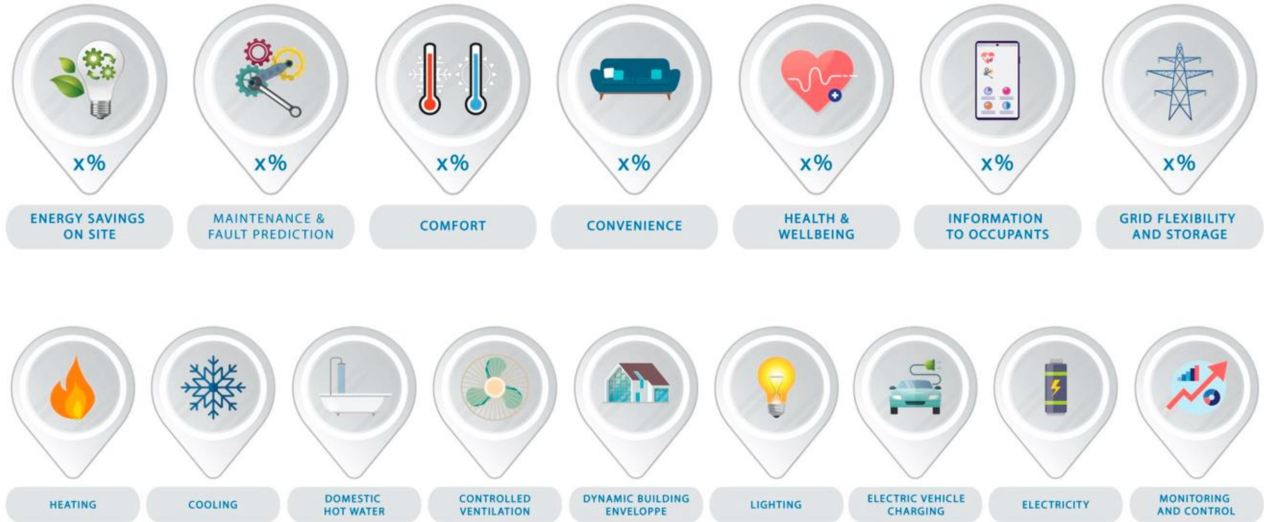

Fig. 1. Smart Readiness Indicators' domains and impact categories [7].

The proposed SRI methodology is based on the assessment of the smart-ready services that can exist in a building. Services that contribute to smart readiness are those that make use of the respective technologies and are examined by the combination of smart technologies that govern them. To support this, two separate lists of smart readiness services have been compiled: a detailed method (Method B) which is suitable for non-residential buildings and a simplified method (Method A) which is mainly suitable for residential buildings as well as small buildings of other uses, each with a separate number of services. Each method lists the services concerned and describes their main expected impact on tenants and the grid [15]. Method C) was only introduced for future development and will concern, in the first stage, a metered/measured method [7].

2.2. SRI Calculations

The smart readiness of a building is evaluated based on the smart-ready services that are installed, planned, or applicable within the building, as well as their corresponding functionality levels. This evaluation is represented through a rating derived from the total SRI score, expressed as a percentage. The score indicates the level of smart readiness achieved by the building or building unit in comparison with its maximum possible smart readiness potential according to EU Regulation 2020/2155 [16].

Based on the catalogue of smart-ready services, the existing services within each technical domain are identified and assessed, and the functionality level of each service is determined according to the criteria defined in the catalogue. The score *I(d, ic)* of each technical domain is determined in **Eq. (1)** as follows:

$$I(d, ic) = \sum_{i=1}^{N} I_{ic}(FL(S_{i,d})) \tag{1}$$

Where *d* represents the technical domain under consideration, and *ic* refers to the specific impact criterion being evaluated. The term *N* indicates the total number of services within the technical domain *d,* and $S_{i,d}$ denotes service *i* belonging to that domain. The expression *FL(Si,d)* corresponds to the functionality level of service *Si,d* as implemented in the building or building unit. Finally, $I_{ic}(FL(Si,d))$ represents the score assigned to service *Si,d* for the impact criterion *ic*, which is determined based on the functionality level of that service.

Advances in Energy Science and Technology
AEST
Amirkabir University of Technology

Eq. (2) shows the maximum score of each technical domain for each impact criterion, $I_{max}(d, ic)$, as shown below:

$$I_{max}(d, ic) = \sum_{i=1}^{N} I_{ic}(FL_{max}(S_{i,d})) \quad (2)$$

In this equation, $FL_{max}(Si,d)$ represents the highest possible functionality level that service *Si,d* can achieve according to the smart-ready services catalogue. Similarly, $I_{ic}(FL_{max}(Si,d))$ refers to the score assigned to service *Si,d* at its maximum functionality level, representing the highest attainable score of that service for the impact criterion *ic*.

The smart readiness score, expressed as a percentage for each of the impact criteria, $SR_{ic,}$ is determined using the weighting specified in **Eq. (3)** below:

$$SR_{ic}(d, ic) = \frac{\sum_{i=1}^{N} W_{d,ic} \times I(d,ic)}{\sum_{i=1}^{N} W_{d,ic} \times I_{max}(d,ic)} \times 100 \quad (3)$$

The term $W_{d,\ ic}$ denotes the weighting factor assigned to technical domain *d* for the impact criterion *ic*, expressed as a percentage. The SRI assessment applies three types of weighting factors related to technical domains and impact criteria to determine the smart readiness of buildings. These include fixed weights, equal weights, and energy balance weights. The energy balance weights are defined based on the major geographical region and also vary between residential and non-residential buildings. In contrast, fixed weights and equal weights remain constant and are not affected by these conditions [10].

Smart readiness scores along the three key functionalities highlighted, as the score for functionality *f* is shown in **Eq. (4)**:

$$SR_f = \sum_{ic=1}^{M} W_f(ic) \times SR_{ic} \quad (4)$$

Where *M* represents the total number of impact criteria, while $W_f(ic)$ denotes the weighting factor, expressed as a percentage, assigned to impact criterion *ic* for the key functionality *f*. The total smart readiness score *SR* may be calculated as a weighted sum of the key functionalities' smart readiness scores, as defined in **Eq. (5)**:

$$SR = \sum W_f \times SR_f \quad (5)$$

W_f is the weight of key functionality f in the calculation of the total smart readiness scores. The summation of W_f should equal 1. Total SRI is expressed as a percentage and reflects the capabilities of the building or building unit to adapt its operation to the needs of the occupants and the grid, and to improve its energy efficiency and overall in-use performance.

2.3. Case Study

The present study is conducted on the educational building of the Physics and Energy Engineering and Industrial Management faculties at Amirkabir University of Technology (Tehran Polytechnic), as shown in **Fig. 2**. This building is located in Tehran, the capital city of Iran, and its construction was completed in 2008. The building is divided into two sections in order to provide an integrated educational space for the mentioned disciplines. However, the technical systems, including the central engine room, are shared between the two sections and provide services to both parts of the building.

The central area of Tehran is characterized by a semi-arid climate with hot, dry summers and relatively cold winters. Due to its geographical location on the southern slopes of the Alborz Mountains, the city experiences significant seasonal temperature variations and limited annual precipitation, most of which occurs during the colder months. Summers are typically long and warm with low humidity, while winters can bring occasional cold spells and moderate rainfall. Urban density and extensive built surfaces in the central districts also contribute to the urban heat island effect, intensifying summer temperatures and influencing local microclimatic conditions [17, 18].

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AEST
Amirkabir University of Technology

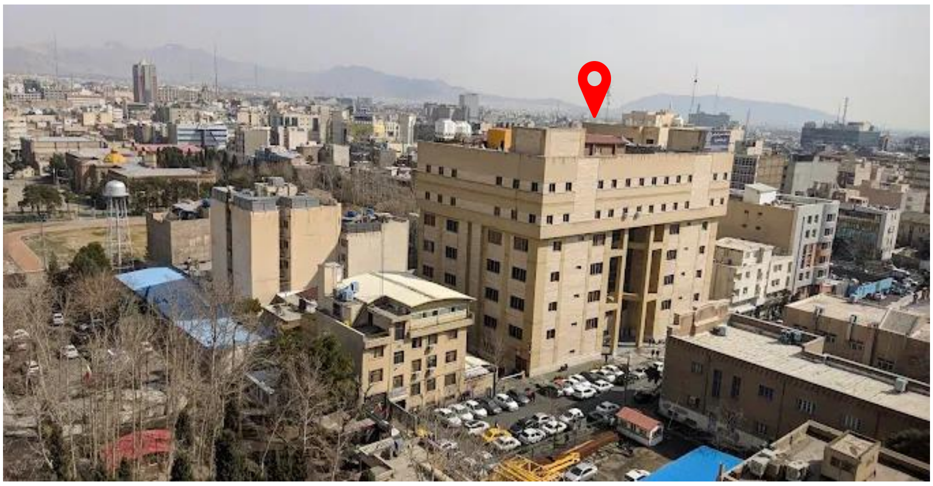

Fig. 2. Physics and Energy Engineering and Industrial Management faculties building.

The building consists of one ground floor and six upper floors. It includes laboratories, conference and meeting halls, classrooms and libraries, administrative offices, and faculty rooms distributed across different floors. The detailed information about the building area and its specifications is presented in **Table 1**. The available data were collected from the technical identification documents provided by the Central Facilities Department of the university.

Table 1. Functional characteristics and floor area of the studied faculty buildings.

Building No.	Floor No.	Function	Floor Area (m^2)	Total Floor Area (m^2)
	Ground	Medical Site	498	
B01		Classroom and Library		
(Physics and	Floor 01	Classroom	420	
Energy Eng.)		Classroom and Laboratory		
	Floor 02	Laboratory	220	
	Floor 03	Faculty room and Office	434	2805.3
		Faculty room, Office and Hall		
	Floor 04		511	
	Floor 05		349.8	
	Floor 06		372.5	
	Ground	Office and Hall	649	
B02	Floor 01	Classroom and Library	211.8	
(Industrial Mgmt.)		Classroom		
	Floor 02	Classroom and Computer Site	118.5	
	Floor 03	Office, Hall and Faculty room	219.5	2616.8
		Office		
	Floor 04	Office	381.5	
	Floor 05		514.5	
	Floor 06		522	

Advances in Energy Science and Technology
AEST
Amirkabir University of Technology

The total floor area of the building refers to the useful floor area within the building envelope that is intended for regular occupancy and functional use. This area typically includes occupied and conditioned spaces such as offices, residential units, corridors, lobbies, classrooms, and commercial areas, while excluding non-usable or non-conditioned spaces such as open parking areas, technical shafts, unused roof spaces, and external balconies [6].

Among nine technical domains defined in this tool, the studied building is equipped with systems in five domains: heating, cooling, domestic hot water, ventilation, and lighting. These systems are located in a central engine room shared between the two faculties. In the engine room, these systems are controlled in a semi-smart manner. Various sensors, including an outdoor temperature sensor, send the required data to a simple monitoring system, and the operator manually adjusts the system settings based on the demand side.

The technical systems located in the shared engine room of the two faculties building are presented in detail in **Table 2**. These systems provide services across different floors and areas of the building based on the room functionality. The systems are classified into system groups in the subsection of each domain represented in the building, and for each of them there is a smart-ready service which defines the functionality level.

Table 2. Active technical systems within the building domains and their functionality levels.

Domain	Description	Functionality Level
Heating	• Fan coil fluid exchanges with boiler • Air handling units	Outside temperature control with reporting historical data
Domestic Hot Water (DHW)	• Coil tank	Automatic control on / off control with reporting historical data
Cooling	• Fan coil fluid exchanges with water-cooled compression chiller • Split and air handling units	Outside temperature control with reporting historical data
Controlled Ventilation	• Exhaust fan • Ventilation fan	Clock control on flow with Constant setpoint temperature
Lighting	• Linear Fluorescent • FBL	Manual on/off switch

As shown in the data presented in **Table 2**, in some domains more than one system is available to provide services. The applied tool requires that a separate assessment entry be created for each system to ensure that the functionality level of none of them is overlooked and that the impact of each system on the building's energy efficiency is evaluated independently [6].

Each system is responsible for providing its services to a specific portion of the building area. For example, fan coil units are used in rooms and laboratories to provide heating and cooling, while in the common areas air handling units are used solely for air circulation. Therefore, determining the effective area served by each service is important for evaluating the performance of that system. This concept is referred to as the "Share of the functionality level", which represents the ratio of the effective serviced area to the total useful floor area of the building [19].

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AEST
Amirkabir University of Technology

3. Results and Discussion

3.1. SRI Tool Modification

After defining the tool and the case study building, the required data must be collected accurately, and the checklist must be completed. Since the building is non-residential and has an educational function, the Method B checklist was selected. This checklist was completed based on field investigations and information obtained from the university's central facilities department. The data used represent the most up-to-date information available from the university in 2026.

One of the main parts of configuring the input data in the checklist is the identification and quantification of the functionality level of the technical systems. The functionality levels reflect the degree of automation, integration, and optimization of technical building systems. The scale ranges from level 0 to 4, representing a gradual progression from conventional systems to fully optimized smart operation [19]:

- **Level 0** – No smart functionality: Conventional systems without automated control.
- **Level 1** – Basic automation: Simple automated control applied to individual building systems.
- **Level 2** – Advanced automation: Enhanced control functions with improved system performance.
- **Level 3** – Integrated and adaptive control: Coordinated operation across multiple building systems responding to operational conditions.
- **Level 4** – Optimized and intelligent control: Fully optimized operation using dynamic data such as occupancy, weather forecasts, and grid signals.

After examining the systems present in the building, it was found that, in the considered domains, the technical systems are mainly at basic functionality levels. Accordingly, when a smart-ready service is applicable, the value assigned to it ranges between 0 and 1. Despite the basic functionality levels of the systems, the monitoring and display system installed in the engine room provides useful information about system performance to the operator. These monitors are capable of displaying real-time data on system consumption and performance locally to the operator.

According to the information obtained from the university's central facilities department, energy consumption data for the faculty buildings are collected remotely at the university's data processing center. This indicates that a suitable database of historical information on the technical systems of the faculty is available. This aspect is considered an advantage for the functionality level of the systems in the reporting services and user interaction category, and it allows the building to achieve a higher SRI score.

The SRI score is thus based on a weighted sum of the 7 total impact scores. In this multi- criteria assessment, the weighting factors can be attributed to both domains and impact criteria to reflect their relative contributions to an aggregated overall impact score. An aggregated SRI score indicates the overall smartness level of the building, while sub-scores allow assessment of specific domains and impact categories [19].

The proposed methodology provides default weighting factors which are differentiated by building type and climate zone [5]. However, these values have been developed for different regions of Europe. To apply this tool in other countries, such as Iran, the method requires the user to define the weighting factors. Researchers [10] and [11] have highlighted the influence of weighting factors on the output results of the SRI and emphasis on the weighting factors. Therefore, the selection among the three previously mentioned weighting approaches becomes necessary.

Advances in Energy Science and Technology
AEST
Amirkabir University of Technology

Considering that this study is being conducted for the first time for the faculty building, the most basic weighting approach has been considered. The equal weighting approach offers the advantage of simplicity and transparency in the calculation of the SRI. In this method, all building services are assigned the same level of importance, which makes the evaluation process easier to understand and implement. This neutrality ensures that no specific system is prioritized over others and allows for straightforward comparison between different building statuses. The equivalent weighting factors are also independent of the type of building and the climate zone and are attributed to all the impact criteria that belong to the key functionality "response to the needs of the occupants [5]. This assumption does not imply that the climatic conditions of the case-study building are insignificant; rather, it was adopted to simplify the initial stage of the research and make it possible to use the results of the study as the basis for subsequent complex studies. Finally, the equal weights are calculated by **Eq. (6)**, where $f_{d,\,ic}$ is the weight of the domain per impact criterion.

$$f_{d,ic} = \frac{100-\sum(Fixed\ weights)}{Number\ of\ revalent\ domains} \tag{6}$$

Considering that five technical domains are present in the studied building, it can be clearly observed that the number of available domains in the denominator of **Eq. (6)** directly influences the weighting distribution.

3.2. SRI Score and Analysis

The assessment of smart readiness was conducted using the SRI calculation sheet version 4.5, which represents the most recent version of the calculation tools available at the time of this study. This standardized tool is structured into several sections to ensure a systematic evaluation. The initial stages of the assessment involve two primary sections: The Information section and the Terms and Conditions section.

In the next step, the user is required to enter the building's general information. A key part of this input concerns the case study characteristics and the selected assessment method. Accordingly, after providing basic data such as the building location, usage type, and status (e.g., original or renovated), the user must specify the building's technical domains and the calculation method within the Methodology section of the tool. In this section, the baseline approach of the present study requires selecting only the technical domains currently available in the building. No assumptions or plans for adding missing domains are considered in the assessment. Furthermore, given the educational state of the building, Method B was selected for the assessment.

In the next section, which concerns the input for the calculation, all technical systems installed in the building were identified, and the functionality level of each was determined in consultation with technical experts. This step is crucial for defining the boundaries of the case study and ensuring that only the systems actually contributing to the building's operation are assessed. Accordingly, the building's engine room is equipped with a semi-smart control system, in which the operator and the system interact in a two-way manner, rather than relying solely on manual operation or fully automated control.

To ensure a precise evaluation, it is necessary to define the assessment scope based on occupant zones. Hence, only the spaces actively used by occupants are considered as the net study area [20]. The main faculty building, with a total floor area of approximately 13,500 m², is shared between two faculties. During the data collection process, the areas of all functional spaces – including classrooms, offices, laboratories, sanitary facilities, and other user spaces – were recorded separately for each faculty in the form of technical data sheets.

Advances in Energy Science and Technology
AEST
Amirkabir University of Technology

In the calculation section, the tool requires the effective area coverage of each service to be expressed as a percentage. Specifically, it must be indicated which functionality level corresponds to each service within its respective zone. Furthermore, the remaining area must be accounted for. Conversely, if no such system is present in the remaining space, the functionality level should be set to 0 to neutralize its impact on the final calculations.

For the purpose of examining the relationship between the service system group and the impact criteria, and also to determine their overall influence on the three key functionalities, equal weighting factors were applied in the calculations. The detailed values of these weights are presented in **Table 3** below.

Table 3. User-defined weighting factors of building's domain – Equivalent weightings

	Energy Efficiency	Energy Flexibility	Comfort	Convenience	Health and Well-being	Maintenance and Predictions	Information to occupants
Heating	20%	25%	20%	20%	00%	25%	25%
DHW	20%	25%	20%	20%	00%	25%	25%
Cooling	20%	25%	20%	20%	00%	25%	25%
Ventilation	20%	25%	20%	20%	100%	25%	25%
Lighting	20%	00%	20%	20%	00%	00%	00%
Total	100%	100%	100%	100%	100%	100%	100%

As shown, the weighting relationship between certain technical domains and impact criteria is fixed at 00% and cannot be modified by the user. This constraint arises from the internal calculation rules and the specific method implemented in the SRI tool. As Becchio et al. [21] noted in their study, although the tool can be adapted for non-European countries through the definition of custom weighting factors, this flexibility also introduces limitations, as users may not be able to fully represent unavoidable influences specific to a given context. They also argued that, due to other methodological constraints, the use of dynamic simulation methods alongside the SRI tool can help address these shortcomings and enable a more comprehensive assessment of building performance.

Weighting distribution across the impact criteria has also been applied equally to ensure that each criterion contributes an equivalent share to the final result. Given that seven impact criteria are defined, each has been assigned a weight of 14.3%. After completing the final settings, the overall SRI score and the detailed results related to the technical domains and impact criteria are presented in **Fig. 3**.

Following the final configuration of the SRI calculation tool, the total SRI score for the university building was determined to be 5.3%. This score places the building within the SRI class of less than 20%. This classification indicates that the building currently exhibits a low level of smart readiness, suggesting substantial room for improvement in adopting and implementing advanced building technologies and control systems [15].

It should be noted that the present study focuses on assessing the current condition of the building. Therefore, to provide a meaningful interpretation of the obtained SRI score, it is appropriate to compare the results with studies that have evaluated existing buildings or baseline conditions prior to the implementation of retrofit scenarios. In [11], experts estimated an SRI score of 26% for the business-as-usual scenario of University Campus buildings in Lithuania. Given the similarities between that case study and the building investigated in the present research in terms of area and function, the comparison clearly indicates that the building examined in this study exhibits a considerably lower level of smart readiness.

Advances in Energy Science and Technology
AEST
Amirkabir University of Technology

A closer examination of the assessment methodology reveals that one of the main differences between the two studies lies in the number and type of domains considered during the SRI evaluation. According to the results reported in [11], the building included additional domains related to “Electricity” and “Monitoring and control”, which contributed positively to its overall SRI score. The absence or limited implementation of such smart-ready services in the case-study building assessed in the present research partly explains the significantly lower SRI value obtained.

A low smart readiness level does not necessarily imply that achieving a higher SRI score is unattainable. On the contrary, previous studies have demonstrated that targeted interventions can lead to significant improvements in building smart readiness. For example, [5] assessed a seven-story office building located in Thessaloniki, Greece; the baseline SRI score was reported to be only 4%. Despite low performance, the authors demonstrated that the implementation of various upgrade scenarios could increase the SRI score to over 60% in all evaluated cases. These findings suggest that buildings with low SRI scores often possess considerable potential for improvement through the integration of smart technologies, automation systems, and advanced control strategies.

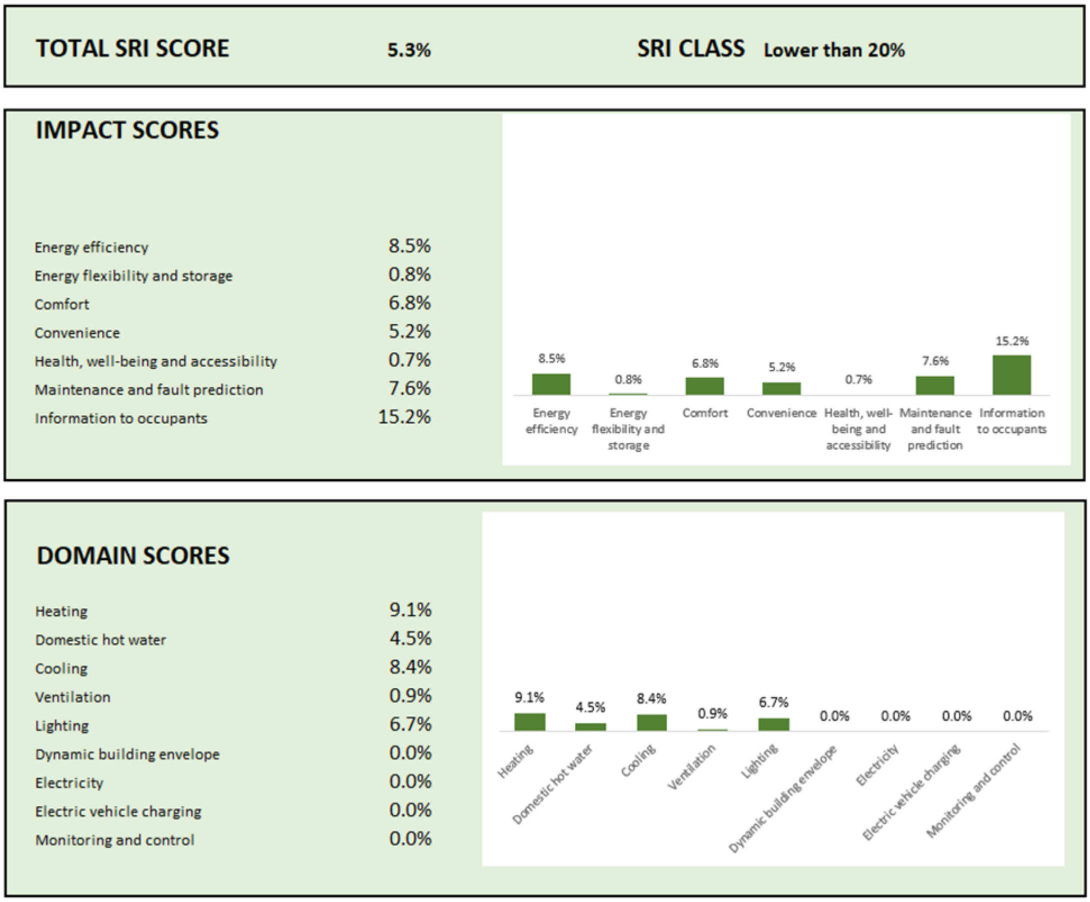

Fig. 3. Total SRI, impact, and domain score of case study building.

A similar trend can be observed in [13], which conducted a comprehensive SRI assessment across different European regions and building typologies. The results indicated that the initial SRI scores of the assessed buildings generally ranged between 5% and 16%. Notably, these buildings were commissioned between 2009 and 2011, which is relatively close to the construction year of the case-study building (2008). This comparison suggests that low baseline SRI scores are not

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AEST
Amirkabir University of Technology

uncommon among buildings constructed before the widespread adoption of smart-ready technologies and building automation systems. Consequently, older buildings often lack advanced monitoring, control, automation, and energy flexibility features, resulting in lower initial SRI scores.

The breakdown of impact scores provides insight into how the building's current systems perform against the seven impact criteria. The highest score was achieved in "Information to occupants" at 15.2%. The prominence relative to other categories is primarily attributed to the capability for real-time data logging and the historical database. However, this functionality is managed through a centralized system; consequently, real-time feedback and data visualization are not available at the local zone for individual occupants. The assignment of functionality level 2 to the Heating, Cooling, and DHW domains—which allows for centralized monitoring and data storage—has been the driving factor behind this higher score.

Following this, "Energy efficiency" and "Maintenance and fault prediction" appear next in the ranking, with scores of 8.5% and 7.6%. These percentages represent the relative contribution of each impact criterion to the building's overall smart readiness score. A higher percentage indicates that the existing technical systems are more capable of supporting that specific smart function. Therefore, the values show that the building has only a modest level of capability in improving energy use and supporting predictive maintenance features.

"Comfort" reflects the building's ability to maintain optimal indoor environmental conditions, whereas "Convenience" pertains to the system's capacity to simplify facility management and enhance user interaction through automation [19]. In this study, these criteria attained scores of 6.8% and 5.2%, respectively, reflecting their limited influence on the overall smart readiness of the building. These low values suggest that the building lacks advanced smart features that are essential for significantly improving occupant satisfaction and operational ease.

In Iran, district heating and cooling networks are non-existent due to the energy resource distribution. As a result, thermal energy services are typically provided locally through independent building systems. The building's interaction with external infrastructure is limited to electricity supply only. In the present study, the building functions as an energy consumer and does not actively interact with the grid. However, the presence of a domestic hot water source provides limited thermal storage capability, which slightly enhances its "Energy flexibility and storage", resulting in a score of 0.8% for the energy flexibility criterion.

Since the only factor influencing the "Health and well-being" impact criterion is ventilation, its contribution in this case remains limited. In the studied building, the ventilation system operates at a low functionality level and serves only a restricted portion of the building area. As a result, the score is calculated to be 0.7%, reflecting the limited presence of smart features related to indoor air quality management.

A review of the domain scores presented in **Fig. 3** shows that the highest values are attributed to the "Heating" and "Cooling" systems, with scores of 9.1% and 8.4%, respectively. The close ranking of these two domains is mainly due to their shared technical infrastructure. The building is equipped with a fan coil system that serves as the distribution platform for both services; depending on the seasonal demand, it is connected either to a boiler for heating or to a water-cooled compression chiller for cooling.

To improve these percentages, enhancements could primarily focus on upgrading the functionality levels of the existing systems. It is important to note that fully automated management of the heating and cooling sources—the boiler and the chiller—can introduce considerable operational risks. Therefore, instead of targeting source automation, it is recommended

Advances in Energy Science and Technology
AEST
Amirkabir University of Technology

that future improvements concentrate on smart upgrading of the fluid and thermal distribution services, where safer and more practical opportunities for performance enhancement are available.

One of the key factors that can enhance the smartness level of the whole building is the effective and coordinated interaction between different technical systems. If these systems are able to share operational data and coordinate their activities with one another, the overall performance of the building can be significantly improved. Such integrated operation can contribute to achieving a higher SRI score.

By reviewing **Fig. 3**, it becomes evident that four domains have a score of 0%, which indicates that these domains are entirely absent in the building. One strategic policy could be to integrate one or more of these missing domains into the building's performance framework. Doing so would increase the current overall SRI score and move the building further along the path toward smartness and intelligent operation.

Aggregated scores typically represent the combined or weighted performance of different components, helping stakeholders understand which areas contribute most to the overall assessment. The output presents aggregated scores for three key functionalities within a system or evaluation framework as below:

- **Key functionality 1 – Energy efficiency** has received a score of 8.1%, representing the highest value among the three key functionalities. This result indicates that energy-related services and operational characteristics constitute the strongest aspect of the smart readiness profile. The functionality encompasses elements associated with energy performance, system operation, energy consumption management, and the efficiency of installed building services. The comparatively higher score suggests that the building possesses a basic level of energy-related functionality that contributes positively to its performance assessment. This may be attributed to the presence of essential building service systems and operational practices that support energy efficiency, even in the absence of advanced smart technologies. Nevertheless, the score remains relatively low in absolute terms, indicating that substantial opportunities still exist for improving energy performance through the implementation of advanced monitoring, control, and energy management solutions.
- **Key functionality 2 – Occupancy comfort** has achieved a score of 7.0%. This result suggests that user-related aspects, including comfort, accessibility, information provision, and occupant interaction with building services, contribute moderately to the smart readiness of the building. The relatively low score can be attributed to the limited implementation of user-centred smart technologies and interactive control systems within the building. The assessment revealed that occupants have limited access to real-time information regarding indoor environmental conditions or energy consumption, and only limited opportunities to interact with building systems through automated interfaces. Such features are commonly associated with higher levels of smart readiness, as they enable occupants to actively participate in optimizing comfort and energy performance. Consequently, the absence of advanced occupant-oriented services restricts the contribution of this functionality to the score.
- **Key functionality 3 – Grid flexibility** has gained a significantly lower score of 0.8%. This result indicates a very limited capacity of the building to interact dynamically with external energy networks or to support demand-side energy management strategies. The assessed building lacks technologies typically associated with grid-interactive and smart-ready buildings, such as advanced energy management systems, demand-response capabilities, energy storage solutions, and automated load-control mechanisms. In the case-study building, no infrastructure was identified that would enable

Advances in Energy Science and Technology
AEST
Amirkabir University of Technology

active participation in grid-balancing services or real-time interaction with electricity network operators. As a result, the contribution of grid-related services to the overall score remains negligible, highlighting a significant opportunity for future improvement through targeted smart-energy upgrades. Overall, the findings indicate that the evaluation is predominantly influenced by building-related and user-oriented functionalities, whereas grid integration currently plays a comparatively limited role.

3.3. SRI Gaps and Future Perspectives

The SRI provides a framework that enables the assessment and comparison of buildings with different conditions across different geographical and climatic contexts. In addition, the methodology allows the development of different scenarios, such as baseline, energy, or smart, depending on the objectives of the study. Several researchers, such as [9] and [10], have taken advantage of this capability to conduct their analyses at broader scales and to explore the performance of buildings under different strategic approaches.

Considering this advantage, it is possible to define a range of short-term and long-term projects for the current condition of one or several buildings from the perspective of a decision-maker or policy-maker, based on different influencing factors. Moreover, the scope of the analysis can be extended beyond individual buildings to the regional, district, or urban scale, enabling the definition of strategic projects at larger spatial scales.

Several limitations of the current SRI framework have been identified, indicating the need for further development and refinement of the methodology. A challenge identified during this research relates to the process of completing the SRI checklist. According to the selected assessment approach in this study (Method B), the checklist can be completed through a self-assessment by a technical expert (No certification) [19]. In practice, the researcher may gather the required information through interviews, field visits to the building, and consultation with technical staff or experts, and then complete the assessment form accordingly.

This flexibility may introduce a degree of subjectivity into the evaluation process. Differences in personal interpretation, experience, or possible misunderstandings of the checklist items can influence how services and functionality levels are assigned. As a result, the reliability and consistency of the final SRI score may be affected, raising questions regarding the accuracy and comparability of the obtained results.

In the present study, the SRI assessment was conducted by a single researcher, following the procedures prescribed by Method B. To reduce potential subjectivity, the assessment was based on multiple sources of evidence, including on-site inspections, interviews with technical personnel, and the review of available building documentation. Where uncertainties arose regarding the classification of services or functionality levels, additional consultations with technical staff were conducted to verify the collected information. Although these measures helped improve the consistency and reliability of the assessment, a degree of evaluator-dependent subjectivity remains inherent to the self-assessment approach and should be considered when interpreting the results.

The SRI concept was introduced in 2017 and was primarily developed based on existing EN standards and the outcomes of the VITO project. Consequently, the framework can still be considered to be in an early stage of development and is likely to undergo revisions and improvements in the future [7]. This is a limitation of the current functionality-level assessment. Improving the scoring mechanism through the use of more comprehensive datasets and the analysis of a larger number of buildings could enhance the reliability of the results.

Advances in Energy Science and Technology
AEST
Amirkabir University of Technology

Overall, these findings suggest that future research should focus on improving the robustness of the SRI methodology, enhancing the accuracy of functionality-level evaluations, and strengthening the integration of SRI with building energy certification systems and EPC-based assessment approaches. It is suggested that future studies focus on the economic feasibility of implementing measures aimed at improving the SRI score of buildings. Evaluating the costs and potential benefits of such interventions can provide a clearer basis for decision-making and help determine whether the adoption of these strategies is economically justifiable in future building management and renovation plans.

4. Conclusion

This study evaluated the smart readiness of the shared building of the Faculties of Physics and Energy Engineering and Industrial Management at Amirkabir University of Technology located in Tehran, using the SRI framework. In the case of the building's usage, which is non-residential, applying the Method B checklist, the technical domains were assessed to determine their current functionality levels and their capacity for energy efficiency and user interaction.

The assessment revealed that the overall SRI score of the building is 5.3%. Among the evaluated technical domains, "Heating" and "Cooling" achieved the highest score, while "Ventilation" showed the greatest need for improvement. These results indicate that while some basic automation is present, there is significant potential for enhancing smartness through integrated control systems and advanced monitoring.

The highest contribution to smart readiness was associated with the building's existing technical systems. Nevertheless, the building demonstrated limited performance in terms of grid connectivity and occupant interaction, highlighting important opportunities for future improvement. Rather than relying solely on large-scale technological upgrades, several practical retrofit measures could significantly enhance the building's smart readiness. Priority should be given to the installation of smart metering and sub-metering systems, occupancy-based lighting and HVAC controls, programmable thermostats, and energy monitoring platforms capable of providing real-time performance feedback. Furthermore, the gradual implementation of an integrated building management system could facilitate the coordination of different technical services, support data collection and analysis, and improve operational decision-making. These interventions represent realistic and cost-effective pathways for increasing the SRI score of existing university buildings.

A key contribution of this research was highlighting the challenges of adapting the European-based framework to other contexts such as Iran. The study found that the reliance on user-defined weighting factors and the subjective nature of the checklist completion – which can be influenced by the evaluator's expertise – are critical factors that can affect the reliability of the final score. Although efforts were made to minimize subjectivity through site inspections, document reviews, and consultations with technical personnel, evaluator judgment remains an inherent limitation of the assessment process.

From a policy perspective, the SRI serves as a valuable decision-making tool for university administrators and facility managers. It allows for the identification of priority areas for retrofitting and helps in defining long-term energy strategies. To improve the effectiveness of SRI in Iran, it is recommended that future studies focus on developing localized weighting factors and conducting economic feasibility analyses for smart upgrades. In addition, evaluating the effectiveness of specific interventions, such as smart metering, automated HVAC control, and occupancy-based management systems, would provide practical guidance for stakeholders seeking to improve the smart readiness of existing educational buildings. Integrating SRI with existing EPC could further provide a more comprehensive overview of building performance, supporting the transition toward smarter and more sustainable educational infrastructures.

Advances in Energy Science and Technology
AEST
Amirkabir University of Technology

Acknowledgments

The authors would like to express their sincere appreciation to the Facilities and Technical Services Department of Amirkabir University of Technology for providing access to building information, technical documentation, and operational data required for this study. Special thanks are extended to the experts and staff who shared their valuable knowledge and experience during site visits and interviews. This research was conducted as part of an academic study, and no external financial support was received.

Author Contributions

S.M.: Writing – original draft, Data collection, Investigation, Formal analysis, Visualization. **M.R.A.:** Conceptualization, Writing – review and editing, Validation, Methodology, Supervision. **F.H.B.:** Resources, Writing – review and editing, Validation, Methodology, Supervision.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The data used in this study were obtained from internal operational records and technical monitoring systems of the faculty of Physics and Energy Engineering and Industrial Management at Amirkabir University of Technology. Due to institutional restrictions and the need to protect the privacy and security of building operational data, datasets cannot be shared openly.

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Advances in Energy Science and Technology
AEST
Amirkabir University of Technology

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