A novel SRI based approach for energy efficiency in university campuses: the case of the University of Udine

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Abstract: The European Union's 2050 Agenda places a strategic focus on energy efficiency, promoting the spread of nearly zero-energy buildings and a transition towards renewable energy sources. In this context, the S3UNICA (Smart SpecialiSation UNIversity CAmpus) project represents a pivotal initiative for advancing energy innovation in university campuses, transforming them into living laboratories for the development and implementation of cutting-edge energy efficiency solutions. A key instrument in this transition is the Smart Readiness Indicator (SRI), introduced by EU Directive 2018/844, which provides a systematic approach for assessing the intelligence and sustainability of buildings. This study, conducted within the S3UNICA framework, presents an enhanced three-tier weighting model designed to refine the SRI calculation, ensuring its applicability across diverse building typologies and climatic contexts. This methodology enhances the precision of SRI evaluations and serves as a robust framework for guiding evidence-based policy decisions and the implementation of targeted energy efficiency interventions. The application of this model to the scientific campus of the University of Udine demonstrated an increase in the SRI score, underscoring the tool's potential as a decision support system for optimising energy policies and fostering innovative sustainability strategies in European university campuses.

Keywords: Smart Readiness Indicator, S3Unica, renewable energy, Sustainability

1. Introduction

In the context of the European Green Deal and the increasing urgency of climate action, the European Union has progressively developed a comprehensive regulatory framework to guide the energy transition of its Member States. In particular, two legislative packages represent key milestones in this evolution: the "Clean Energy for All Europeans" package and the subsequent "Fit for 55" package. The former, adopted between 2018 and 2019, marked a significant overhaul of the EU's energy regulatory framework, introducing measures aimed at promoting energy efficiency, increasing the share of renewable energy sources, encouraging active consumer participation in the energy market, and progressively decarbonising the building stock (European Parliament, 2019). The second legislative package, proposed in 2021, significantly elevated the level of political and regulatory ambition by setting a target of a 55 % reduction in net greenhouse-gas emissions by 2030 relative to 1990 levels (EC, 2021). Rather than supplanting its predecessor, the "Fit for 55" package reinforces and extends the Clean Energy for All Europeans framework by updating both targets and instruments in line with the EU's long-term climate-neutrality objectives (Council of the European Union, 2023). Structurally and functionally, the two packages are deeply interrelated: the Clean Energy package laid the regulatory and technical foundations for a just and integrated energy transition, while "Fit for 55" consolidates that groundwork, broadening the scope to encompass key sectors such as transport, the built environment and carbon border adjustments, and promoting a more incisive, results-oriented governance.

Considering that the built environment accounts for approximately 40 % of total energy consumption and 36 % of greenhouse-gas emissions in Europe (Maduta et al., 2023), the recast Energy Performance of Buildings Directive (2018/844/EU) introduced the Smart Readiness Indicator (SRI) as an optional certification scheme designed to assess and promote building "intelligence" across the Union (Canale et al., 2024). The SRI quantifies a building's ability to leverage information and communication technologies and electronic systems to adapt operations to both occupant needs and grid demands, thereby enhancing overall energy performance (Directive 2018/844/EU). This assessment is structured around three core smart-readiness functionalities: the capacity to maintain energy performance and operational efficiency through adaptive consumption management; the capacity to modulate operational modes in response to occupant requirements—ensuring usability, healthy indoor climates and transparent energy-use feedback; and the capacity to flexibly manage the building's aggregate electricity demand, including participation in active, passive, implicit and explicit demand-response mechanisms.

Across Europe, the deployment and evaluation of the Smart Readiness Indicator (SRI) methodology have been undertaken in diverse building contexts. In Italy, research efforts have primarily concentrated on establishing the technical foundations required for SRI implementation within the national building stock (Canale et al., 2024). Vigna et al. (2020) conducted an SRI assessment of the Italian residential sector under several scenario assumptions, identifying eight "smart building typologies" with estimated SRI values spanning from 5.0 % to 27.5 %.

In Greece, the application of the SRI to a typical 1960s office building undergoing deep renovation revealed very low baseline scores (4 %–8 %)—a reflection of obsolete systems, inefficient energy performance and substandard indoor comfort—while post-retrofit scenarios exhibited marked improvements, achieving up to 60 % in the first scenario and 67 %–68 % in subsequent ones, thereby demonstrating the capacity of targeted interventions to substantially enhance building intelligence (Chatzikonstantinidis et al., 2024). Similarly, Horák et al. (2019) applied the SRI framework to three residential buildings and one educational facility in the Czech Republic, and Janhunen et al. (2019) evaluated two educational buildings of different construction periods and an office in Helsinki. Ramezani et al. (2021) further tested the methodology on two Portuguese buildings, concluding that, despite limitations in forecasting energy consumption across end users, the SRI framework adapts effectively to Mediterranean climatic conditions. Fokaides et al. (2020) pointed out that the implementation of SRI in listed buildings, typical of historic structures, is significantly hampered, limiting the integration of innovative technologies.

Moreover, the manner in which partial implementation of smart functionalities is treated introduces ambiguity, rendering the SRI outcome dependent on the user's interpretation and thereby undermining the repeatability and comparability of results to buildings equipped with similar technology portfolios (Becchio et al., 2021; Vigna et al., 2020). To mitigate this, Vigna et al. (2018) proposed anchoring the SRI to a quantitative performance metric to facilitate cross-building comparisons. Geographic applicability has also been called into question, with Janhunen et al. (2019) noting that cold-climate countries lack specific smart-ready service definitions within the catalogue, and that the presence of district heating can negatively affect comparability, despite its recognized importance for future energy efficiency (Simeoni et al., 2019; Ciotti et al., 2019). Furthermore, the SRI tool's emphasis on control system readiness rather than the intrinsic efficiency of the underlying technologies limits its ability to capture the full scope of energy performance improvements (Becchio et al., 2021). Delavar et al. (2025), in their comprehensive review of Smart Readiness Indicators (SRIs) and their applications, highlight that although these indicators were originally developed for residential (multi-family), non-residential (office), public (schools, hospitals) and large buildings with a useful floor area of more than 500 m^2, their scope of application can extend well beyond these types. In this context, it is interesting to explore the integration of SRI with Industry 5.0 principles, extending the analysis to the "built environment" of infrastructures that host production processes and industrial activities, with the aim of increasing the well-being, sustainability and resilience of the entire system. This perspective is founded on the convergence of a number of pillars, common to both SRI and the Industry 5.0 paradigm:

- *System resilience and flexibility*: in both building and manufacturing contexts, the ability to adapt to energy supply disruptions or demand variations is crucial. Smart demand response capabilities, included in SRI domains, can therefore support business continuity and strengthen the overall resilience of the industrial ecosystem.
- *Sustainability and energy efficiency*: Industry 5.0 promotes low-impact and circular economy processes; SRIs, in turn, incentivise smart consumption management and the integration of renewables and storage systems. In the industrial environment, this translates into optimising the energy loads of machinery, intelligent climate management of production areas and progress towards carbon neutrality of plants.
- *Human centricity and comfort at work*: Industry 5.0 places the well-being of workers at the centre of production strategies. Similarly, SRIs include criteria for thermal control, indoor air quality and adaptive lighting. The adoption of such technologies in industry can therefore improve productivity, health and employee satisfaction, fully in line with the human-centricity principle of Industry 5.0

Through this integrated approach, industrial buildings are no longer conceived only as an envelope, but as active components of a "smart" production system, capable of supporting and enhancing the pillars of Industry 5.0.

As part of the SRI evolution, the Smart SpecialiSation UNIversity CAmpus (S3UNICA) project - funded by the Interreg Europe Low Carbon Economy program and involving nine partners in different Member States - aims to enhance the energy efficiency of infrastructures through the development of a holistic methodological approach. The core of S3UNICA is the adoption of a system of standardised indicators - the SRI - aimed at measuring the "smartness" of each infrastructure and at integrating, along the entire value chain and involving all stakeholders, the actions carried out by individuals with regional, national and European energy policies. In addition, it enables the design and implementation of specific measures on all areas of the built environment - from civil residential to non-residential buildings and industrial infrastructures - favoring a harmonisation of interventions that consistently responds to the efficiency, sustainability and resilience needs of each context. Within the project, the method was applied to the context of university campuses. Indeed, university campuses, as dense aggregations of buildings, infrastructure and services, act as complex microcosms of industrial and urban districts with significant energy requirements (Pierce et al., 2024; Almasri et al., 2024). Consequently, they provide ideal environments for experimenting with decarbonisation and sustainability strategies. This tool has also been extended to guide the formulation of action plans within the Regional Energy Plan, thus promoting coherent, indicator-based energy planning. This paper summarises this methodology and applies the decision support tool to evaluate the SRI of the University of Udine.

The remainder of the article is organised as follows: Section 2 describes the SRI-based decision-support framework; Section 3 details its application to the University of Udine campus; and Section 4 presents concluding remarks.

2. The decision support tool

As part of the project, we developed a methodology that integrates spatial planning with the SRI framework, using a decision support tool to identify the most effective interventions to optimise the energy performance of infrastructure. Figure 1 illustrates the general decision support framework. In an area, the Energy Plan is a strate-

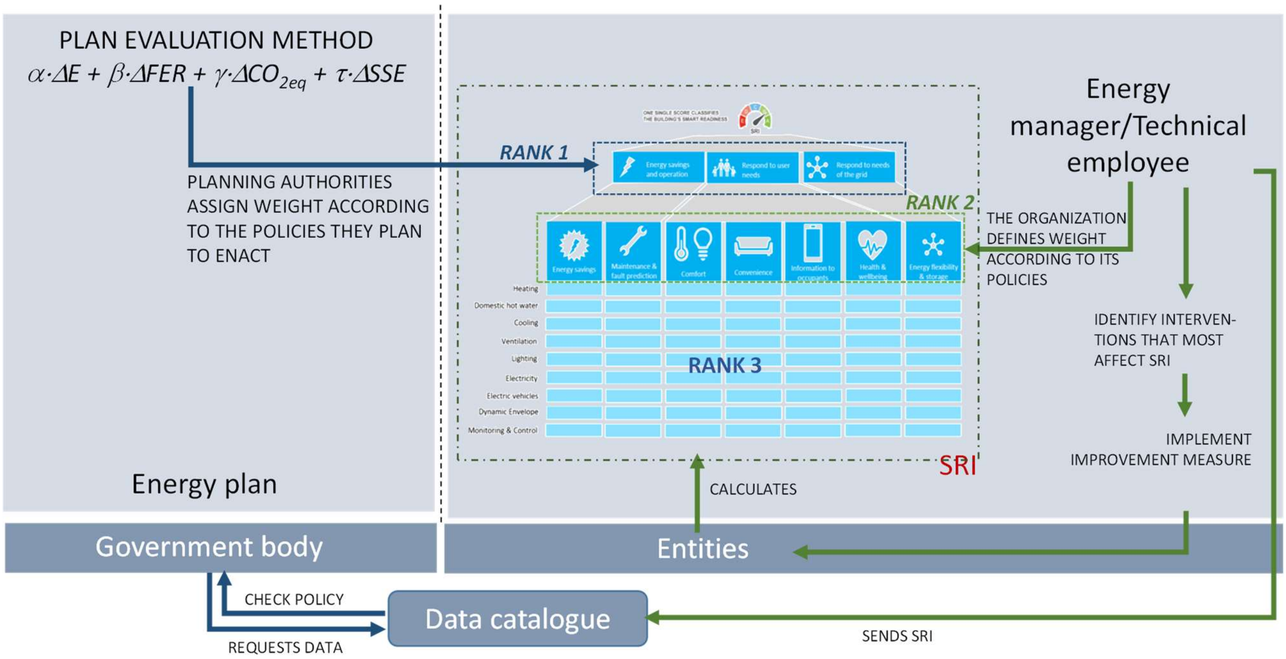

Figure 1. Scheme of the developed decision support system

gic and operational document that outlines, at national, regional or local level, the path to secure a safe, sustainable and efficient energy supply in the medium to long term. Within the plan, the methodology involves prioritisation whereby candidate measures are ranked according to four specific benefits: increased energy efficiency (ΔE), spread of renewable energy (ΔRES), reduction of greenhouse gas emissions (ΔCO_2eq) and improved socio-economic performance (ΔSEP). These benefits are aggregated into a total plan score through the weighted sum:

$$Van,t=\alpha\ \Delta E+\beta\ \Delta RES+\gamma\ \Delta CO2eq+\tau\ \Delta SSE$$

where the weighting coefficients (α, β, γ, τ) are defined by the planning authority as a synthesis of qualitative drivers (e.g., political priorities) and quantitative factors (e.g., distance to 2030 targets or the 2050 roadmap).

Building upon this, the Smart Readiness Indicator (SRI) methodology proposed by Vito-Waide (European Commission, 2020) evaluates a building’s “smart-ready” services—those leveraging intelligent technologies to enhance energy performance, occupant comfort and grid interaction. Fifty-two such services (sub-domains) are organized into nine technical domains (Heating; Domestic Hot Water; Cooling; Controlled Ventilation; Lighting; Dynamic Building Envelope; Electricity; Electric Vehicle Charging; Monitoring and Control). Each sub-domain is scored on a functionality scale from 0 to 4, where higher levels denote greater system intelligence and thus confer larger benefits. Service scores are first assessed against seven sub-impact criteria reflecting their effects on energy consumption, maintenance, comfort, convenience, occupant information, well-being and energy flexibility. These sub-impact criteria are then consolidated into three principal impact criteria—energy performance and operation, response to occupant needs, and energy flexibility intelligence and thus confer larger benefits. Service scores are first assessed against seven sub-impact criteria reflecting their effects on energy consumption, maintenance, comfort, convenience, occupant information, well-being and energy flexibility. These sub-impact criteria are then consolidated into three principal impact criteria—energy performance and operation, response to occupant needs, and energy flexibility.

To tailor the SRI tool to diverse building contexts—accounting for factors such as construction age, geographic location and regional efficiency objectives—a three-tiered weighting scheme has been implemented. The first level allows the organisation's policy makers to adjust the influence of each impact criterion on the overall SRI score (Rank 1 in fig.1). The second level allows plant energy managers to calibrate the contribution of individual sub-impact criteria to the corresponding impact criteria (Rank 2 in fig.1). The third level allows the relative importance of each technical domain within each sub-impact criteria to be modified (Rank 3 in fig.1). By introducing these configurable rankings, the framework not only adapts to specific policy and environmental conditions but also functions as a continuous monitoring mechanism: stakeholders can record and compare innovative, high-impact solutions in a shared database, thereby facilitating the scalable deployment of best practices across multiple sites.

To support both the tool operator and stakeholders in selecting among potential interventions for the building under study, we implemented an interactive, tabular display to guide the data-entry process. For each assessed subdomain, the tool provides a detailed description of the characteristics and key technologies associated with each functional level, thereby enabling users to assign the most appropriate level according to the specific context. This visualization is shown in Figure 2. Once functional levels have been entered, the tables report the percentage variation in the overall SRI score for each subdomain arising from the application of alternative functional levels. These changes are computed by applying the three-tier weighting scheme described above, thereby enabling users to identify the intervention that delivers the greatest impact on the SRI.

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					Functionality level				
Domain	**Code**	**Theme**	**Service group**	**Smart ready service**	**0**	**1**	**2**	**3**	**4**
Heating	H-S1	Controllability of Performance: Emission	Heat control - demand side	Heat emission control					
	H-S2a	Controllability of Performance: Production	Control heat production facilities	Heat generator control (all except heat pumps)					
	H-S2b	Controllability of Performance: Production	Control heat production facilities	Heat generator control (heat pumps)					
	H-S3	Storage & Connectivity	Control heat production facilities	Storage and shifting of thermal energy					
	H-S4	Reporting functionalities	Information to occupants and facility management	Report information regarding heating system performance					
Domestic hot water	DHW-S1	Controllability of Performance	Control DHW production facilities	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)					
	DHW-S2	Storage & Connectivity	Flexibility DHW production facilities	Control of DHW storage charging					
	DHW-S3	Information to occupants	Information to occupants and facility managers	Report information regarding domestic hot water performance					
Cooling	C-S1	Controllability of Performance: Emission	Cooling control - demand side	Cooling emission control					
	C-S2	Controllability of Performance: Production	Control cooling production facilities	Generator control for cooling					
	C-S3	Storage & Connectivity	Flexibility and grid interaction	Flexibility and grid interaction					
	C-S4	Reporting functionalities	Information to occupants and facility managers	Report information regarding cooling system performance					
Controlled ventilation	V-S1	Controllability of Performance	Air flow control	Supply air flow control at the room level					
	V-S3	Reporting functionalities	Feedback - Reporting information	Reporting information regarding IAQ					
Lighting	L-S1	Controllability of Performance	Artificial lighting control	Occupancy control for indoor lighting					
Dynamic building envelope	DE-S1	Controllability of Performance	Window control	Window solar shading control					
	DE-S3	Reporting functionalities	Feedback - Reporting information	Reporting information regarding performance					
Electricity	E-S1	Storage & Connectivity	Storage	Storage of (locally generated) electricity					
	E-S2	Reporting functionalities	Electricity Loads	Reporting information regarding electricity consumption					
	E-S3	Reporting functionalities	Renewables	Reporting information regarding local electrcity generation					
	E-S4	Reporting functionalities	Storage	Reporting information regarding energy storage					
Electric vehicle charging	EV-S1	Storage & Connectivity	EV Charging	Charging capacity					
	EV-S3		EV Charging - Grid	EV Charging Grid balancing					
	EV-S4	Reporting functionalities	EV Charging - connectivity	EV charging information and connectivity					
Monitoring and control	MC-S1	Controllability of Performance	TBS interaction control	Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy weather and grid signals					
	MC-S2	Flexibility	Smart Grid Integration	Smart Grid Integration					
	MC-S3	Information to occupants	Feedback - Reporting information	Central reporting of TBS performance and energy use					

Figure 2. Interactive table of sub-domain functional levels

3. Application

The University of Udine comprises a heterogeneous portfolio of buildings differing in architectural style and construction period, dispersed across various city districts. Among these, the Rizzi complex and its associated laboratories—constituting the institution’s scientific campus—serve as the principal hub for teaching and research activities, encompassing a total floor area of 90,415 m^2 and a gross volume of 346,940 m^3. These facilities accommodate the majority of the student population and account for approximately 50 % of the university’s total energy consumption.

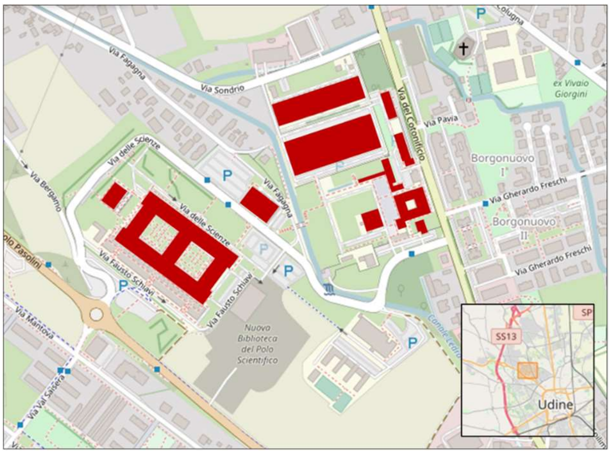

Figure 3. Buildings of the Rizzi Scientific Campus at the University of Udine.

Site-specific monitoring protocols are in place whereby electrical energy flows are recorded on a monthly basis for each building, while thermal energy consumption is logged daily. Electrical supply is provided by the national grid supplemented by a 32 kW$_p$ on-site photovoltaic installation, yielding an annual electricity demand of 9,266,715 kWh. Thermal energy, amounting to roughly 5,050 MWh per year, is delivered via district heating, which recovers waste heat from the civil hospital’s trigeneration plant fueled by a blend of natural gas and bio-oil.

In order to enhance overall energy performance, several retrofit measures have been planned. The existing lighting infrastructure will be entirely replaced with high-efficiency LED fixtures integrated into an adaptive daylight-harvesting control system, thereby achieving further reductions in electrical consumption. Concurrently, Internet-of-Things (IoT)–based control technologies for both heating and cooling systems will be deployed to enable fine-grained data acquisition, with the dual aim of optimizing occupant comfort and minimizing energy use. Finally, the photovoltaic array is slated for expansion to a total installed capacity of 500 kW$_p$, significantly increasing the share of on-site renewable generation.

As previously described, the assessment framework was applied to a University of Udine building to determine its Smart Readiness Indicator both before interventions and as forecasted upon their completion. Thereafter, using the table of implemented measures, the improvement attributable to the planned interventions was confirmed, illustrating the framework’s role as an effective decision-support tool. For the SRI calculation, the university’s technical team selected a functionality level for each sub-domain defined in the assessment protocol. The values corresponding to these selected levels are presented in Table 1.

The third weighting rank was selected from those recommended by Vito-Waide (European Commission, 2020) according to the building’s geographic context; for an Italian site, the “Southern Europe” set was adopted.

Table 1. Functionality level for the examined building

Domain	Sub-domain code	Functionality level
Heating	H-S1	2
	H-S2a	2
	H-S2b	0
	H-S3	2
	H-S4	2
Domestic hot water	DHW-S1	0
	DHW-S2	1
	DHW-S3	2
Cooling	C-S1	2
	C-S2	2
	C-S3	1
	C-S4	1
Ventilation	V-S1	2
	V-S3	0
Lighting	L-S1	1
Dynamic building envelope	DE-S1	0
	DE-S3	0
Electricity	E-S1	1
	E-S2	2
	E-S3	2
	E-S4	1
Electric vehicle charging	EV-S1	0
	EV-S3	0
	EV-S4	0
Monitoring and Control	MC-S1	1
	MC-S2	1
	MC-S3	1

Both the second and third ranks were then configured by assigning equal weight to each sub-impact criterion within its respective impact criterion, and equal weight to each impact criterion within the overall SRI. These weighting factors were defined in consultation with technical staff and sector experts to ensure the configuration best reflects the local climatic conditions and the specific technical-functional characteristics of the buildings under study. The resulting values for all weighting factors are presented in Table 2.

Table 2. Selected weightings factors: a) third rank, b) second rank, c) first rank

	Energy savings on site [%]	Maintenance & fault prediction[%]	Comfort [%]	Convenience [%]	Health & wellbeing [%]	Information to occupants [%]	Flexibility for the grid and storage [%]
H	1.35	4.00	0.79	0.39	0.00	2.08	0.28
DHW	0.90	4.00	0.00	0.78	0.00	0.69	0.28
C	1.35	6.67	1.19	0.78	0.60	2.08	0.56
V	0.90	0.00	0.40	0.19	2.38	1.39	0.83
L	0.90	0.00	0.40	0.19	0.00	0.00	0.00
DE	1.35	0.00	1.19	0.78	1.79	1.39	0.83
E	0.90	2.67	0.00	0.58	0.00	2.78	1.11
EV	0.00	8.00	0.00	1.16	0.00	0.00	0.83
MC	1.35	1.33	0.00	0.97	0.00	1.39	0.56

[1] a)

Energy savings	Maintenance & fault prediction	Comfort	Convenience	Health & wellbeing	Information to occupant	Flexibility for the grid and storage
50%	50%	25%	25%	25%	25%	100%

[1] b)

Energy Saving and operation	Respond to user needs	Respond to needs of the grid
33.33%	33.33%	33.33%

[1] c)

Table 2(a) shows the absolute numerical weights assigned to the nine technical services evaluated: heating (H), domestic hot water (DHW), cooling (C), ventilation (V), lighting (L), demand energy management (DE), energy integration (E), electric vehicle charging (EV) and micro-cogeneration (MC). These are then compared against the seven identified impact criteria: on-site energy savings, maintenance and fault prediction, comfort, convenience, health and wellbeing, information for occupants and grid flexibility and storage. Table 2(b) then normalises these values into relative percentages for each of the seven criteria, providing an overview of the overall weight of each impact in the Smart Readiness Indicator calculation at the second aggregation level. In this phase, on-site energy savings and predictive maintenance contribute 50% each to the score, while comfort, convenience, health, and information for occupants contribute 25% each, and grid flexibility and storage contribute 100%. Finally, Table 2(c) represents the highest hierarchical level, where the three strategic macro-objectives — Energy saving and operation, Respond to user needs, and Respond to needs of the grid — are equally weighted at 33.33% each. This ensures that energy savings, occupant satisfaction and grid compatibility exert the same influence on the final SRI value in the aggregate.

The SRI value obtained from this set of functionality levels and weightings is equal to 32.70 %.

Table 3. SRI percentage increment (or decrement) table.

		Functionality level				
Domain	Code	0	1	2	3	4
Heating	H-S1	-5.0	-3.86	-2.13	-0.62	0.00
	H-S2a	-1.69	-0.84	0.00		
	H-S2b	-10.14	-6.48	-5.63	0.00	
	H-S3	-5,63	-2.82	0.00		
	H-S4	-5.69	-3.46	-3.13	-2.81	0.00
Domestic hot water	DHW-S1	-2.45	-0.68	0.00		
	DHW-S2	-3.62	-2.35	0.00		
	DHW-S3	-3.26	-1.62	-1.30	-0.98	0.00
Cooling	C-S1	-1.66	-0.89	-0.32	0.00	0.00
	C-S2	-0.39	-0.19	0.00	0.00	
	C-S3	-1.40	-1.08	-0.77	-0.65	0.00
	C-S4	-1.09	-0.77	-0.45	-0.12	0.00

Table 3 presents the increments of the SRI achievable for each sub-domain. Using this tool, one can identify the intervention that maximizes the increase in the final SRI value. Specifically, for each sub-domain the table quantifies the percentage variation in SRI associated with each functional level. By knowing the effect on the overall SRI resulting from the application of a given functional level to each sub-domain, the optimal intervention can thus be selected. This approach supports stakeholders in integrating these results with a techno-economic analysis, enabling informed decision-making and the prioritization of interventions based on their effectiveness.

Application of the functional levels and their respective weighting factors yields significant results: enhancements to control systems and information-reporting technologies, together with renovation of the lighting system, deliver the greatest benefits in terms of SRI.

Analysis of the residual increase potential shows that the "cooling" sub-domain exhibits the highest value (13.22 %), followed by "electric vehicle charging" (10.00 %) and "heating" (8.89 %). The lowest potentials are observed in the "monitoring and control" (5.60 %) and "lighting" (1.49 %) sub-domains.

4. Conclusions

The results of this study show that integrating the Smart Readiness Indicator (SRI) model, which is calibrated using a three-level weighting scheme, provides an effective framework for supporting decisions about targeted energy actions. The developed framework proved to be both robust and flexible and it supports integration with continuous monitoring platforms. The application to the University of Udine's scientific campus confirmed the model's ability to objectively quantify the "smartness" of a building, as evidenced by the observed increase in SRI score, and to swiftly identify the most effective measures. The inability to obtain the maximum indicator value, which is attributable to the presence of non-'smart ready' systems and the conservation constraints inherent to historic structures, highlights the need to expand the catalogue of available technologies and refine the weighting criteria for diverse building typologies (Ramezani et al., 2021; Becchio et al., 2021) as well as for industrial contexts. The SRI model's modularity and participatory approach enable its application across different settings, provided a structured process involving weight calibration, service catalogue adaptation and ICT infrastructure verification is followed. Future developments will extend the method to the principles of Industry 5.0, employing the building-"smartness" framework to foster a more sustainable, resilient, and human-centred industry. From this perspective, applying the SRI to warehouses and production facilities will enable the technological maturity of HVAC, lighting and environmental monitoring systems to be evaluated in line with Industry 5.0 requirements. Deploying advanced sensors can safeguard worker health in critical sectors such as chemicals, pharmaceuticals and electronics by ensuring adequate levels of comfort and safety. Integration with predictive maintenance systems leveraging digital twins and artificial intelligence algorithms will provide a holistic view to optimise interventions on building and process systems, thereby reducing unplanned machine downtime. Similarly, extending the functionalities of the SRI for demand response will enable the synchronisation of start-stop operations for non-critical auxiliary equipment with production schedules, thereby contributing to peak demand reduction. Finally, integrated digital twins combining production and environmental data will enable energy efficiency, comfort and overall performance scenarios to be simulated, thus reflecting a building's smart maturity according to the SRI. This evolution will require the definition of composite indicators representing interoperability between building and process systems, while aligning productivity and worker wellbeing objectives. These methodological advances address both the specific needs of industrial contexts and ensure that corporate strategies align with emerging technologies and policies. This provides a robust foundation for guiding energy and industrial policies towards sustainable innovation.

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