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Applicability of the Smart Readiness Indicator for Cold Climate Countries

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Abstract: In the EU's revised Energy Performance of Buildings Directive (EPBD), a smart readiness indicator (SRI) was introduced as an energy efficiency activity to promote smart ready technologies (SRT) in the building sector. The proposed methodology is based on the evaluation of building services and how they contribute on SRT. The purpose of this paper is to explore the applicability of the SRI to cold climate countries in Northern Europe. The Northern European countries are an interesting test environment for the indicator because of their advanced information and communication technology and high building energy consumption profiles. The findings imply that regardless of the SRI's conceptualization as a system oriented (smart grid) approach, in its current form, it was not able to recognize the specific features of cold climate buildings, specifically those employing advanced district heating (DH) systems. Another, more practical, implication of the study was that due to the subjective nature of the proposed process for selecting SRI relevant building services, the applicability of SRI as a fair rating system across the EU member states is problematic.

Keywords: smart readiness indicator; EPBD; smart ready technologies; smart grid; energy efficiency; district heating

1. Introduction

In recent years, there has been a growing interest in energy efficiency activities in the European Union (EU). This interest arises from the EU's need to use energy more efficiently, lower European energy bills, increase energy self-sufficiency, and improve environmental protection [1]. These activities target sectors with the greatest potential to reduce energy consumption and improve efficiency, such as buildings and transportation [2]. As stated in the Energy Efficiency Directive (EED) [3], the existing building stock represents the single largest potential for energy savings. Overall, buildings are responsible for one third of the total energy consumption worldwide [4]. In the EU, the built environment accounts for approximately 40% of the current energy consumption [2].

The European Commission (EC) has introduced digitalization as a key effort in improving the efficiency of the European energy markets in the revised Energy Performance of Buildings Directive (EPBD) [1]. As the electricity system in Europe becomes more decentralized and decarbonized, it must also become more digitalized in order to stay competitive, affordable, and secure [5]. Digitizing the electricity system requires development of synergies among the energy, information, and communication technology (ICT) sectors to deliver intelligent energy products and services across Europe [6]. According to several studies, the overall efficiency in the built environment is predicted to increase when the electricity systems with their central operators—smart grids—are combined with the energy systems, such as heating and cooling systems and gas grids [7–10]. In such future "smart energy systems," the energy grids are responsible for the intelligent management and operation of synergistically interconnected energy networks [11,12]. The smart energy utilization based on demand is, in general, expected to become an essential part of future sustainable and renewable energy systems [13]. In the revised EPBD [1], the digitalization of the energy systems was expected to quickly change the energy landscape by integrating the renewables to smart grids and smart-ready buildings. The digitalization of the building sector and the transition toward "smart buildings" will, however, require the adoption of innovative business models, such as the EC-driven Digital Single Market, and technology development [1].

In general, the adoption of digitalization is considered as a requirement for achieving not only the EU's 2020 target for nearly zero-energy buildings (nZEB) [14], but also the 2030 long-term energy efficiency and renewable energy targets and the 2050 carbon economy goal [1]. According to recent studies, the European building stock is, however, far from being smart-ready today [15]. Therefore, the Commission is currently strongly directing the EU-level energy efficiency activities to support the transition toward smart buildings. For instance, the Horizon 2020 program has supported 42 smart building-related actions between its beginning in 2014 and early May of 2017 [16]. One EC-driven activity is the ongoing development of a smart readiness indicator (SRI) for buildings. The SRI-related project was launched in early 2017 as an action toward the Commission's goal to encourage the uptake of ICT and smart technologies in the building sector [17]. In the revised EPBD [1], the indicator was introduced as an optional EU framework for assessing the capabilities of a building to adapt its operation to the needs of the occupant and the grid and to improve its energy efficiency and overall performance.

Some of the key aims in the revised EPBD are to increase the share of renewable energy production, increase energy efficiency according to the EU policy framework [18], and increase European energy security, competitiveness, and sustainability [1]. Thereby, the SRI aims to promote the key goals outlined in the directive. Ideally, the framework would provide an equal rating system across the EU member states and would provide the added value of building smartness that is more tangible for the building users, owners, tenants, and smart service providers [19]. However, to realize the original purpose of the SRI, its methodological framework should be equally applicable over all climate regions in the EU. It could be argued that one of the greatest opportunities to make significant improvements in the building sector in terms of energy performance [1] is found in the cold climate regions. In Northern Europe, for instance, heating accounts for a major portion of building energy use [20], and some cold climate-specific heating solutions, such as district heating (DH), have been widely applied to improve the overall energy efficiency in this region of Europe [21]. A key question remains to be answered: Is the current SRI framework (i.e., the EU-wide energy efficiency activity) applicable in cold climate regions? A significant energy-related potential exists, but the market specific technologies in cold climate regions might differ from the baseline design for the European SRI.

This is the first study to explore the applicability of the SRI to cold climate countries in the EU. The methodological framework builds on the assessment of the SRI relevant building services. The applicability and technological fit of the service catalog is studied from the point of view of cold climate buildings. In order to collect the data for the study, we conducted an SRI assessment for three buildings in the Northern European country of Finland.

What became apparent from our study was that the SRI framework, regardless of its origin as a system oriented (smart grid) solution, was not able to recognize the specific features of cold climate building practices, specifically those of an advanced DH system. The framework covered DH as a heating supplying method but did not recognize its nature as a highly optimized energy grid integration system, which features a huge thermal energy storage capability. From a practical perspective, it was found that the SRI methodology still allows too many subjective choices, which increase the risk of "manipulating" scores to obtain more favorable results. The partial inconsistences in the proposed process for selecting SRI relevant building services were found to diminish the potential of SRI as an equally applicable rating system across the EU member states.

The paper is divided into five chapters. In the second chapter, we introduce the SRI framework and calculation methodology. We utilized the SRI methodology as the theoretical structure for the experimental SRI assessments, which we further elaborate on in the third chapter. The data gathered from the assessments are analyzed and the results presented in the fourth chapter. In the fifth chapter, we discuss the key findings and relate them to the key goals outlined in the revised EPBD, as well as draw conclusions about the applicability of the SRI to cold climate buildings.

2. Smart Readiness Indicator

The smart readiness indicator (SRI) for buildings was introduced as an EU-level energy efficiency activity in the proposal to amend the EPBD in 2016 [17]. One of the key goals in developing such an indicator was to raise awareness amongst building owners and occupants of the value behind building automation and electronic monitoring of the technical building systems (TBS) [1] and to overall encourage the uptake of smart ready technologies (SRT) in the building sector [17]. An SRI study team was commissioned by the EC Directorate-General (DG) Energy to create the definition of the SRI and a methodology by which it is to be calculated. The SRI methodology, which was used in this study, was introduced in the final report of its first technical support study [19]. The final report was published in August of 2018. Recently, the second technical support study has been launched to deliver the technical inputs needed to refine the developed methodology [22]. In this chapter, we describe the proposed SRI methodological framework and its calculation methodology.

2.1. Methodological framework

The SRI framework is built on the catalog of "smart ready services", which are enabled by a combination of various SRT. In total, the full-fledged catalog contains 112 services, but because not all of them are equally realizable in practical experiments, a streamlined set of services has been provided by the SRI study team. The structure of the smart ready service catalog is divided into 10 distinct domains:

1. Heating
2. Domestic hot water
3. Cooling
4. Controlled ventilation
5. Lighting
6. Dynamic building envelope
7. On-site renewable energy generation
8. Demand side management
9. Electric vehicle charging
10. Monitoring and control

In the streamlined framework, these domains together cover 52 smart ready services, and each service can be implemented with various degrees of smartness (i.e., functionality levels). The main domain of heating, for instance, consists of 11 smart ready services and one service—heating-1a: heat emission control—that can be implemented in five different functionality levels. In the framework, the functionality level 0 indicates a nonsmart service implementation and the highest level—which varies from service to service—refers to a developed functionality, where control is based on demand. Each smart ready service has, additionally, potential impacts on the building occupants, the building itself, and the grid. The impacts have been grouped into eight distinct categories: energy savings on site, flexibility for the grid and storage, self-generation, comfort, convenience, wellbeing and health, maintenance and fault prediction, and information available to occupants.

2.2. Calculation methodology

The overall SRI score is a result of a multicriteria assessment, which leads to a single score that expresses how close (or far) the building is from its theoretical maximum smartness. The calculation methodology is founded on the selection of the SRI relevant building services (i.e., triage process), as some domains and services are not relevant (i.e., applicable) due to local and site-specific context. The services, which are not applicable, are omitted from the assessment and thus do not influence the overall score. Thereafter, only the applicable services' functionality levels are determined in the assessment. Each SRI relevant service and their functionality levels have a predefined impact score in each of the eight impact criteria. Once the service level impacts are known, an aggregated score is calculated for each of the 10 distinct domains. The domain level impact score is calculated as the ratio between individual and theoretical maximum scores of the domains' services. If heating-1a, for instance, would have been implemented on the functionality level 2 in a building, its respective impacts from the levels 2 and 4, would be calculated as part of the main domain's aggregated score. In such case, the impacts of that service and the ratio would be calculated as it is displayed in Table 1.

Table 1. The impacts of heating-1a and the ratio, when the service has been implemented on functionality level 2 in a building.

Heating-1a	Energy	Flexibility	Self-g.	Comfort	Convenience	Wellbeing	Maintenance	Information
Level 2	2	0	0	2	2	0	0	0
Level 4	3	0	0	2	3	0	1	0
Ratio	2/3	N/A	N/A	2/2	2/3	N/A	0/1	N/A

For each impact criterion, a total impact score is calculated as a weighted sum of the domain impact scores, where the weight of a given domain will depend on its relative importance for the considered impact. The overall SRI score is finally derived as a weighted sum of the eight total impact scores. The more detailed exemplifications for calculating the overall SRI score and adapting the service level impacts and domain-based weightings can be found in the final report of the first technical support study [19].

3. Research design

This study was designed to evaluate the applicability of the recently introduced SRI methodology to cold climate countries. The SRI case assessments were utilized as the dataset for completing the technological fit analysis of the smart ready service catalog and the selection of applicable services. The detailed inspection of the later multicriteria valuation steps of the SRI protocol was left out of this study because it focuses on technological fit analysis. We applied the so-called streamlined SRI framework in the study. The case assessments were conducted in three cold climate country buildings.

3.1. SRI Case Assessments

The SRI assessment of the study covered two phases: first, the technological fit comparison of the smart ready service catalog, and second, the inspection of the process for selecting the SRI relevant building services. The first phase of the study was carried out by assessing the smart service levels of each domain in the catalog. All the available 52 smart ready services with their degree of smartness were assessed in order to analyze the technological fit of the smart ready service catalog for cold climate countries. The actual and maximum functionality levels of each individual service were listed on one spreadsheet. In the analysis, we highlighted services that were not implemented or were implemented only as nonsmart services in the case buildings. We also eventually discuss the SRT, which we identified as applicable in the assessments but were not listed in the streamlined smart ready service catalog.

In the second phase of the study, we focused on the technological fit of the proposed process for selecting the applicable services (i.e., the triage process). First, we analyzed the rationale of the triage process, which was proposed in the SRI methodological framework. Second, based on the analysis, we produced two other triage evaluations and performed altogether three triage processes. The results from the first study phase were utilized to process the SRI relevant building services. In the first triage process experiment, which followed the SRI primary suggestion, we omitted every service that was identified as unavailable in the initial study phase. In the second experiment, we inspected the unavailable services more closely and omitted only the services that were not implemented in the case buildings due to some other compensating SRT implementation. In the third experiment, we considered all the services "applicable" and did not omit any of the services. The aim of the study was to analyze how the relatively subjective process of selecting the SRI relevant building services influences the final results. Finally, we discuss the relevance of the triage process in general within the SRI multicriteria assessment process.

3.2. Case Buildings

The SRI case assessments, which were used as the dataset for completing the technological fit inspection, were completed for three case buildings: a modern educational building (case X), a regular educational building (case Y), and a traditional office building (case Z). All three buildings are located in the Helsinki metropolitan region in Finland. The case buildings varied in terms of their year of construction, floor area (in terms of m^2), and energy efficiency classification. The energy efficiency of the buildings was measured with the Energy Performance Certificate (EPC) class. The key characteristics of the case buildings are shown in Table 2 below.

Table 2. Key characteristics of the case buildings.

Case	Year of Constr.	Area	EPC Class	Location	Specialty
X	2018	47500	A	Metropolitan region, rail connection	The building is 90% self-sufficient in heating and cooling through geothermal heat. Solar panels on the roof partly cover the electricity demand.
Y	2015	8641	B	Metropolitan region, bus connection	District heating covers the building's energy demand. An advanced CO_2-based ventilation control has been implemented.
Z	2004	14205	E	Metropolitan region, rail connection	District heating covers the building's energy demand. A sophisticated central controlled cooling block system has been implemented.

The SRI assessments took place on the premises of the case buildings in October of 2018. The assessments for the buildings were performed in workgroups consisting of the case buildings' TBS specialists and the researchers as the SRI evaluation team members. The sessions started with a presentation of the smart ready service catalog, and the assessments were performed by using a qualitative checklist approach. The TBS specialists indicated the implemented functionality levels for the applicable smart ready services, and the evaluation team filled the scores into an Excel-based calculation tool, which aggregated the overall SRI scores. The calculation tool was prepared by the evaluation team beforehand in accordance with the SRI methodological framework.

3.2.1. A Modern Educational Building

The workshop for this building was arranged by the first author of this paper. The third author of the paper performed the role of a practical actor representing both the SRI evaluation team and the property manager. The case building's building service manager and the electricity project manager performed the roles of TBS specialists. Because the building had recently been constructed, the TBS specialists could determine almost all of the functionality levels without consulting the technical documents. Only a few service levels had to be double checked from the documents. The workshop took approximately one hour. A preliminary SRI assessment of the building was made a few months before the building was opened for educational use in May of 2018. The assessment session at the time included an extensive walk-through inspection, including the public spaces, the engine room, and the roof.

3.2.2. A Regular Educational Building

The workshop for this building was arranged by the second author of this paper. The author performed the role of a practical actor representing both the SRI evaluation team and the property manager. The first author attended the workshop as the SRI evaluation team member. The case building's facility manager performed the role of a TBS specialist. The workshop was held in one of the building's meeting rooms on the first floor. The TBS specialist could determine most of the functionality levels without consulting the technical documents, but some of the services were checked after the workshop session from the central TBS operating computer. The workshop took approximately two hours, including a brief walk-through of the public premises of the building.

3.2.3. A Traditional Office Building

The workshop for this building was arranged by the second author of this paper. The author performed the role of a practical actor representing both the SRI evaluation team and the property manager. The first author attended the workshop as the SRI evaluation team member. The case building's facility manager performed the role of a TBS specialist. The workshop was held in one of the meeting rooms on the first floor. The facility manager had had operational responsibility for the building's TBS for several years and was able to determine all the functionality levels without consulting the technical documents. The workshop session took approximately two hours. The assessment did not include a walk-through inspection of the building's office premises.

4. Results

The detailed inspection of the SRI case assessment data samples provided evidence to address the research question regarding the applicability of the SRI in a cold climate country. The analysis covered the technological fit comparison of the smart ready service catalog and the triage process in the context of the case buildings.

4.1. Technological Fit of the Smart Ready Service Catalog

The first phase of this study—the technological fit comparison of the smart ready service catalog—was completed by analyzing the case buildings' smart service levels in accordance with the streamlined SRI framework. The analysis covered the 10 main domains and all available 52 smart ready services. We analyzed the technological fit by comparing, service-by-service, the actual functionality levels to the maximum ones in each case building. In this chapter, we will introduce the service level results by domain. The resulting functionality levels are marked as "AF/MF" in Tables 3–12, where "AF" is the actual and "MF" the maximum functionality level for a specific service. The analysis was especially focused on the applicability of the services listed in the service catalog, which either were not implemented or were implemented only as nonsmart services in the case buildings. The functionality levels of the unavailable services are marked as "0/0" and the nonsmart ones as "0/MF" in the tables.

4.1.1. Heating

The main domain of heating covers 11 smart ready services in the streamlined service catalog. The inspection of the services and the determination of the actual functionality levels took more than half of the time allocated for the assessment process in each case building. The heating related smart ready services represented the largest portion of the catalog. Additionally, the description of a few services was not explicit in terms of the cold climate buildings, which raised discussion within the workgroups. The resulting heating related functionality levels in the case buildings are displayed in Table 3.

The results we obtained reveal that none of the three case buildings featured thermos-active building systems (TABS) or thermal energy storage (TES) in the main domain of heating. Among the TBS specialists, both systems were identified as rather rare implementations in a cold climate building.

The relevance of TABS in general was challenged due to known issues regarding its adjustability. Instead, the realization of a separate TES system in the case buildings was generally considered an unnecessary implementation because the applicable heating supplying method district heating (DH) features a giant thermal energy storage capability. DH was applied as a backup energy source for geothermal heat in case building X and as the main heating supplying method in case buildings Y and Z. Heating-2b and heating-2c services were not implemented in case buildings Y and Z because these buildings had only one heat generator.

Table 3. The functionality levels in the main domain of heating.

Code	Service	Case X	Case Y	Case Z
Heating-1a	Heat emission control	3/4	3/4	3/4
Heating-1b	Emission control for TABS (heating mode)	0/0 *	0/0	0/0
Heating-1c	Control of distribution fluid temperature (supply or return air or water flow)	2/2	1/2	2/2
Heating-1d	Control of distribution pumps in networks	3/4	1/4	1/4
Heating-1e	Intermittent control of emission and/or distribution	2/3	1/3	1/3
Heating-1f	Thermal Energy Storage (TES) for building heating (excluding TABS)	0/0	0/0	0/0
Heating-1g	Building preheating control	1/2	1/2	1/2
Heating-2a	Heat generator control (for combustion and district heating)	1/2	1/2	1/2
Heating-2b	Heat generator control (for heat pumps)	2/3	0/0	0/0
Heating-2c	Sequencing of different heat generators	3/3	0/0	0/0
Heating-3	Report information regarding heating system performance	2/4	2/4	2/4

* 0/0 indicates that the specific service was not implemented (i.e., not applicable) in the case building.

4.1.2. Domestic Hot Water

The main domain of domestic hot water (DHW) covers four smart ready services in the service catalog. The assessment of the smart ready services in this domain appeared as rather irrelevant, since only one of four services was applicable in the case buildings. The resulting DHW related functionality levels in the case buildings are displayed in Table 4.

The smart ready services listed in the domain of DHW featured functionalities in the hot water storage charging capabilities. However, in the case buildings where DH was an applicable heating supplying method, this capability was considered irrelevant among the TBS specialists. The DH system itself features a giant storage charging capability and is already regularly highly optimized on the supplier side, which decreases the need for a separate hot water storage charging system on the demand side.

Table 4. The functionality levels in the main domain of domestic hot water (DHW).

Code	Service	Case X	Case Y	Case Z
DHW-1a	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	0/0	0/0	0/0
DHW-1b	Control of DHW storage charging (using hot water generation)	0/0	0/0	0/0
DHW-1d	Control of DHW storage charging (with solar collector and supplementary heat generation)	0/0	0/0	0/0
DHW-3	Report information regarding domestic hot water performance	2/4	2/4	2/4

4.1.3. Cooling

The main domain of cooling covers 10 smart ready services in the catalog. The services listed under the cooling domain are almost identical to the heating related services, which decreased the time spent on the assessment. The resulting cooling related functionality levels in the case buildings are displayed in Table 5.

Because the TABS- and TES-related technologies were not implemented in the case buildings, cooling-1b and cooling-1g were marked as unavailable services in the table above. Additionally, case building Y was missing the SRT in the services related to the control of the distribution network (cooling-1c and cooling-1d). In the workgroup sessions, it was highlighted that the relevance of various cooling systems in general can be questioned within the context of cold climate buildings. Due to the dominant weather conditions, there is no regular need for cooling related services, which is one reason for the lack of implementation of such services. The cooling related actual functionality levels in all three case buildings appeared relatively low.

Table 5. The functionality levels in the main domain of cooling.

Code	Service	Case X	Case Y	Case Z
Cooling-1a	Cooling emission control	4/4	1/4	3/4
Cooling-1b	Emission control for TABS (cooling mode)	0/0	0/0	0/0
Cooling-1c	Control of distribution network chilled water temperature (supply or return)	0/2 *	0/0	2/2
Cooling-1d	Control of distribution pumps in networks	4/4	0/0	4/4
Cooling-1e	Intermittent control of emission and/or distribution	0/3	1/3	1/3
Cooling-1f	Interlock between heating and cooling control of emission and/or distribution	2/2	2/2	1/2
Cooling-1g	Control of Thermal Energy Storage (TES) operation	0/0	0/0	0/0
Cooling-2a	Generator control for cooling	0/2	1/2	2/2
Cooling-2b	Sequencing of different cooling generators	1/3	0/3	2/3
Cooling-3	Report information regarding cooling system performance	2/4	2/4	2/4

* 0/MF indicates that the specific service has been implemented as a nonsmart service in the case building.

4.1.4. Controlled Mechanical Ventilation

The main domain of controlled ventilation (MV) covers eight smart ready services. The assessment of the related services was a straightforward and explicit process because all the services listed in the catalog were considered relevant in the case buildings. The resulting MV-related functionality levels in the case buildings are displayed in Table 6.

Table 6. The functionality levels in the main domain of mechanical ventilation (MV).

Code	Service	Case X	Case Y	Case Z
MV-1a	Supply air flow control at the room level	2/3	3/3	1/3
MV-1b	Adjust the outdoor air flow or exhaust air rate	2/3	2/3	1/3
MV-1c	Air flow or pressure control at the air handler level	2/4	1/4	1/4
MV-2a	Room air temp. control (all-air systems)	2/2	1/2	1/2
MV-2c	Heat recovery control: prevention of overheating	0/2	1/2	1/2
MV-2d	Supply air temperature control	2/3	3/3	3/3
MV-3	Free cooling with mechanical ventilation system	2/3	0/3	0/3
MV-6	Reporting information regarding IAQ	1/3	1/3	0/3

The services in the main domain featured various functionalities in room temperature and air flow pressure control. Every service listed in the catalog was implemented at least as a nonsmart service in the case buildings. However, the rationale of the MV-3 appeared ambiguous in an office building according to the TBS specialists. From the perspective of cold climate buildings, the smart ready service catalog was missing icing protection, the importance of which was highlighted by the specialists. The service was listed in the full-fledged smart ready service catalog, but it was omitted in the streamlined version.

4.1.5. Lighting

The main domain of lighting covered two smart ready services. The assessment process was straightforward and did not raise any questions. The resulting lighting related functionality levels in each case building are displayed in Table 7.

Table 7. The functionality levels in the main domain of lighting.

Code	Service	Case X	Case Y	Case Z
Lighting-1a	Occupancy control for indoor lighting	3/3	2/3	1/3
Lighting-2	Control artificial lighting power based on daylight levels	4/4	2/4	1/4

The importance of a developed lighting system in cold climate buildings was highlighted by the TBS specialists. Due to the constant need for lighting during the majority of the year, the related SRT are generally well realized, as reflected in the case assessments. The most advanced lighting related technologies were present in case building X, in which the maximum smartness of the services was attained.

4.1.6. Dynamic Building Envelope

The main domain of dynamic building envelope (DBE) covers two smart ready services. The resulting DBE related functionality levels in the case buildings are displayed in Table 8.

Table 8. The functionality levels in the main domain of dynamic building envelope (DBE).

Code	Service	Case X	Case Y	Case Z
DBE-1	Window solar shading control	1/4	0/4	0/4
DBE-2	Window open/closed control, combined with HVAC system	0/3	0/3	0/3

The utilization of the DBE is an important feature in cold climate buildings from an energy efficiency perspective, as was pointed out by the TBS specialists. The SRT related to window solar shading control (DBE-1) was considered a technology that positively influences the overall efficiency of cold climate buildings. The implementation of the service was, however, mainly manual in the case buildings. On the contrary, the DBE-2 service was considered of low relevance or irrelevant in the case buildings. Due to the dominant weather conditions, window open/close control was not considered an applicable feature in cold climate country buildings.

4.1.7. Energy Generation

The main domain of energy generation (EG) covers four smart ready services in the catalog. The assessment of the services was relevant only in case building X because the related SRT were not implemented in case buildings Y and Z. The resulting EG-related functionality levels in each case building are displayed in Table 9.

As can be seen from the table above, the EG-related SRT were implemented only in case building X. However, the services were implemented mainly as nonsmart services. The locally generated energy in case building X can be utilized immediately throughout the year. Therefore, the proposed storage-related service implementations (EG-3 and EG-4) were not put into practice in case building X according to the case building's TBS specialists. The importance of the combined heat and power (CHP) solutions (EG-5) in general was challenged by the TBS specialists due to the low cost-efficiency of the technology in cold climate buildings.

Table 9. The functionality levels in the main domain of energy generation (EG).

Code	Service	Case X	Case Y	Case Z
EG-2	Reporting information regarding energy generation	2/4	0/0	0/0
EG-3	Storage of locally generated energy	0/3	0/0	0/0
EG-4	Optimizing self-consumption of locally generated energy	0/2	0/0	0/0
EG-5	CHP control	0/1	0/0	0/0

4.1.8. Demand Side Management

The main domain of demand side management (DSM) covers four smart ready services. It was the only domain in the smart ready service catalog that was completely missing from all three case buildings. Although the domain was not implemented, the theme raised discussion in the workgroups. The resulting DSM-related functionality levels are displayed in Table 10.

Table 10. The functionality levels in the main domain of demand side management (DSM).

Code	Service	Case X	Case Y	Case Z
DSM-18	Smart Grid Integration	0/0	0/0	0/0
DSM-19	DSM control of equipment	0/0	0/0	0/0
DSM-21	Reporting information regarding DSM	0/0	0/0	0/0
DSM-22	Override of DSM control	0/0	0/0	0/0

The TBS specialists did not consider the realization of the electric grid network related services relevant in the case buildings. In all three case buildings, however, another type of energy grid—district heating—was implemented, but it was not considered a DSM-related technology in the smart ready service catalog.

4.1.9. Electric Vehicle Charging

The main domain of electric vehicle charging (EV) covers three smart ready services. The related services were available only in case building X because the vital SRT were not implemented in case buildings Y and Z. The resulting EV related functionality levels in the case buildings are displayed in Table 11.

Table 11. The functionality levels in the main domain of electric vehicle charging (EV).

Code	Service	Case X	Case Y	Case Z
EV-2	EV Charging Capacity	2/3	0/0	0/0
EV-16	EV Charging Grid balancing	1/2	0/0	0/0
EV-17	EV charging information and connectivity	0/2	0/0	0/0

According to the TBS specialists, the EV technologies and related charging capabilities are well implemented in the new constructions. In the less modern buildings, the related technologies appear to be missing, and this was also determined from the case assessments.

4.1.10. Monitoring and Control

The main domain of monitoring and control (MC) covers four smart ready services. The assessment of the services appeared as a straightforward process, and the actual functionality levels were easy to detect. The resulting functionality levels in the case buildings are displayed in Table 12.

Every smart ready service in the domain was implemented at least as a nonsmart service in all of the case buildings. The service related to the central reporting of the TBS performance and energy use (MC-13) was identified by the specialists as an advanced SRT, which are generally implemented only in modern buildings. The case assessment results supported the notice; only case building X featured developed smartness in the specific service.

Table 12. The functionality levels in the main domain of monitoring and control (MC).

Code	Service	Case X	Case Y	Case Z
MC-3	Run time management of HVAC systems	2/3	2/3	2/3
MC-4	Detecting faults of technical building systems and providing support to the diagnosis of these faults	0/2	2/2	2/2
MC-9	Occupancy detection: connected services	1/2	1/2	1/2
MC-13	Central reporting of TBS performance and energy use	3/3	0/3	0/3

4.2. Technological Fit of the Triage Process

The second phase of this study, the technological fit comparison of the triage process was completed by analyzing the rationale of the selection of the applicable services. The triage process has a major influence on the SRI score of the assessed buildings, and is thus included in the analytical focus of this paper. The analysis covered the inspection of the potential triages in the case assessments and the influence of the subjective decisions on the case buildings' smart readiness scores.

In the previous chapter, we introduced the actual functionality levels, which we determined in the case assessments, and highlighted the services that we found unavailable in the case buildings. The triage process aims to, in line with the SRI guidelines, omit those unavailable services to increase the relevance of the SRI assessment. It is, however, important to note that the triage process influences not only what services are assessed, but also how the results are interpreted. Every service that is excluded from the assessment decreases the maximum attainable score, which increases the final SRI score. Therefore, variance in the number of assessed services makes comparing SRI scores across properties more difficult. As an example, one can ask whether two buildings with the same final SRI score can be considered equally "smart ready" if one has 35 and the other 45 applicable services.

The SRI methodological framework recommends excluding irrelevant services from the assessment, but it is vague on how such an approach influences the comparability of the final scores among buildings. Based on the triage process, which was proposed in the SRI methodology, we developed two other methods to complete the selection of the applicable services. The methods and their rationale are presented in Table 13 below, in which method A represents the current SRI guidelines.

In the previous chapter, we assessed the actual functionality levels of all available 52 smart ready services listed in the streamlined catalog. In practice, the assessment completed therein followed the SRI guidelines (triage method A) because the maximum functionality level of the unavailable services did not increase the maximum attainable score.

Table 13. The triage methods for selecting the applicable services in the case buildings.

Triage Method	Description	Rationale
A	Select only relevant services. If the property does not have a particular service, exclude it from the assessment.	Maximum relevance for a property. The final score reflects the smart readiness of existing services, as some services are not meaningful to implement in all properties.
B	Exclude overlapping services. When there is more than one service listed for the same function, assess only the service(s) relevant for the property.	Compromise between comparability and relevance. The maximum attainable scores will vary slightly, but properties are not punished for having, for example, only one service for domestic hot water storage charging.
C	Select all services. If a service is not implemented for the property, its functionality level is 0.	Maximum comparability between properties, as the maximum attainable score is always the same.

In this chapter, we will analyze how the selection of the applicable services influences the case buildings' smart readiness. The resulting level of smart readiness in the case assessments is expressed as "AF/MF," where "AF" is the sum of the actual functionality level and "MF" is the sum of the maximum functionality level (MF) of the SRI relevant building services. The results are introduced by triage methods in Tables 14–16. The actual functionality levels, which we introduced in Tables 3–12 in the previous chapter, are not influenced by the triage process and thus are utilized to calculate the smart readiness.

4.2.1. Triage Method A

The assessment process of triage method A follows the SRI guidelines. In practice, all the services marked as "0/0" in Tables 3–12 were omitted from the smart ready service catalog. Thereafter, the maximum functionality level (i.e., the maximum attainable smartness) was restricted in line with the number of the applicable services. The number of applicable services and the resulting level of smart readiness in each case building are displayed in Table 14.

Table 14. The resulting level of smart readiness after triage process A.

	No. of Applicable Services			Smart Readiness (AF/MF %)		
Domain	Case X	Case Y	Case Z	Case X	Case Y	Case Z
Heating	9	7	7	70%	48%	52%
DHW	1	1	1	50%	50%	50%
Cooling	8	6	8	54%	39%	71%
MV	8	8	8	57%	52%	35%
Lighting	2	2	2	100%	57%	29%
DBE	2	2	2	14%	0% *	0%
EG	4	0	0	20%	N/A **	N/A
DSM	0	0	0	N/A	N/A	N/A
EV	3	0	0	43%	N/A	N/A
MC	4	4	4	60%	50%	50%
Total	41	30	32	55%	44%	47%

* 0% indicates that the domain related services were considered applicable for the case building; thus, their MF did increase the maximum attainable smartness. ** N/A indicates that all the domain related services were considered irrelevant for the case building; thus, their MF did not increase the maximum attainable smartness.

In triage process A, all services that were not considered applicable to the case buildings by the specialist team were omitted from the smart ready service catalog. In practice, this means that 11 smart ready services in total were considered irrelevant for case building X, 22 for case building Y, and 20 for case building Z. Thereafter, the maximum attainable smartness was considerably higher for case building X. As a result of triage process A, the resulting level of smart readiness was close to 50% in total. This result appears not to be in line with the different level of SRT implemented in the case buildings. This is an interesting observation because it raises the question of how such an approach affects the comparability of different buildings in which different service implementations have been realized.

4.2.2. Triage Method B

Triage method B represents a compromise between the maximum relevance of the specific property and the maximum comparability between the properties. In practice, this means that the applicability of the services marked as "0/0" in Tables 3–12 were reconsidered. The number of applicable services and the resulting level of smart readiness in each case building are displayed in Table 15.

Table 15. The resulting level of smart readiness after triage process B.

	No. of Applicable Services			Smart Readiness (AF/MF %)		
Domain	Case X	Case Y	Case Z	Case X	Case Y	Case Z
Heating	11	9	9	59%	38%	42%
DHW	1	1	1	50%	50%	50%
Cooling	10	10	10	45%	24%	59%
MV	8	8	8	57%	52%	35%
Lighting	2	2	2	100%	57%	29%
DBE	2	2	2	14%	0%	0%
EG	4	4	4	20%	0%	0%
DSM	4	4	4	0%	0%	0%
EV	3	3	3	43%	0%	0%
MC	4	4	4	60%	50%	50%
Total	49	47	47	47%	30%	34%

As a result of triage process B, the number of applicable services was greater in all three case buildings than after triage process A. Thus, the maximum attainable smartness was also greater. In triage process B, all the services considered to be overlapping with some other SRT by the specialist team were omitted from the smart ready service catalog. In practice, this means that a total of three smart ready services were considered irrelevant for case building X and five for case buildings Y and Z. Compared to the results after triage process A, the level of smart readiness was lower in domains in which the number of applicable services was increased. Triage process B appeared to highlight the SRT-related differences among the case buildings but, at the same time, the relevance of the case building specific scoring did decrease. Additionally, the rules for deciding which services are relevant for a given property are up to interpretation, and different assessors could get different results, which throws into doubt the accuracy of the overall scoring.

4.2.3. Triage method C

Triage method C provides maximum comparability among properties. Thus, all the smart ready services listed in the streamlined catalog were considered relevant in the case assessments. In practice, all the unavailable services marked as "0/0" in Tables 3–12 in the previous chapter were considered as nonsmart services in the case assessments. The number of applicable services and the resulting level of smart readiness in each case building are displayed in Table 16.

Table 16. The resulting smart readiness after triage process C.

No. of Applicable Services				Smart Readiness (AF/MF %)		
Domain	Case X	Case Y	Case Z	Case X	Case Y	Case Z
Heating	11	11	11	59%	31%	34%
DHW	4	4	4	15%	15%	15%
Cooling	10	10	10	45%	24%	59%
MV	8	8	8	57%	52%	35%
Lighting	2	2	2	100%	57%	29%
DBE	2	2	2	14%	0%	0%
EG	4	4	4	20%	0%	0%
DSM	4	4	4	0%	0%	0%
EV	3	3	3	43%	0%	0%
MC	4	4	4	60%	50%	50%
Total	52	52	52	45%	27%	30%

After triage process C, the number of applicable services was equal in all three case buildings. Compared to the results after triage processes A and B, the level of smart readiness in the case buildings was lower in accordance with the increased number of applicable services. Compared to the current SRI guidelines, triage process C decreased the total level of smart readiness by 10 percentage points for case building X and 17 percentage points for case buildings Y and Z. Triage process C appears to yield results that are fully comparable to each other. However, this process does not provide a realistic image of the current level of smart readiness in a specific building because services that are not viable within the building are still taken into account.

5. Discussion

This paper presents the first study to examine the applicability of the EU's smart readiness indicator (SRI) methodology to cold climate countries. The applicability of the SRI was observed from its technological fit point of view covering the comparability of the smart ready service catalog and the selection of SRI relevant building services. The aim of the study was to examine whether the SRI was able to carry out its original purpose outlined in the revised EPBD in cold climate country buildings. From the study, it was found that without any changes in the baseline design for the European SRI, the framework appeared to be not to be fully applicable to cold climate countries or to encourage the realization of potential smart ready technologies (SRT) in the building sector.

The first phase of the study was to observe the technological comparability of the smart ready service catalog to cold climate buildings. The presence of district heating (DH) was found to have the greatest unfavorable impact on comparability, which was a surprising finding because DH has been predicted to be a key enabler in future energy systems [23–25], and energy flexibility is expected to become one of the key resources in Europe [26]. In European cold climate countries—such as Finland, Sweden, Denmark, Poland, and Russia—DH covers ~50% of all national heat demand in buildings [27]. In this study, DH was found to be the main reason for the lack of implementations of various thermal energy storage (TES) system capabilities, which influenced the technological fit of the smart ready service catalog in the heating, cooling, domestic hot water (DHW), and energy generation (EG) domains.

The study's results also revealed that some of the cold climate country-specific technologies were not listed in the proposed smart ready service catalog. In the catalog, the DSM-related services were found to feature functionalities only in electric grids. Some of the related services could, however, be equally applicable to other types of grids—such as district heating and cooling grids—which are both common thermal energy system implementations in cold climate countries [25]. The opportunity to employ DH as an energy grid technology was introduced in the final report of the first SRI technical support study [19], but it was not realized in the proposed streamlined version of the smart ready service catalog. Currently, the SRI covers only the demand side of the energy grid and, in the context of DH, the smartness in the system today exists on the supply side. Thereafter, it is questionable whether the SRI should also cover the supply side of the related implementations to increase the applicability of the SRI to cold climate countries.

From the technological fit point of view, the SRI methodology was lacking the ability to support the uptake of thermal energy system related SRT, which according to the study appeared to decrease the most the SRI's applicability to cold climate countries. The applicability could, however, be improved by extending the content of the SRI service catalog to cover also the demand response capabilities of the energy grids, such as district heating. As the incorporation of energy grid related SRT is expected to support the European Commission's 2050 Energy strategy for a secure, competitive, and decarbonized energy system [28], the proposed extension in the SRI's scope could support better the key goals outlined in the revised EPBD [1] and improve the uptake of SRT in the growing energy systems market in Europe.

The second aim of this study was to observe the technological fit of the introduced process for selecting SRI relevant building services (i.e., the triage process) to cold climate buildings. In our study, we found two main issues in the current calculation methodology that appeared to decrease the general applicability of the SRI. First, the triage method, which followed the current SRI guidelines, appeared not to produce comparable assessment results. Second, the methodology allows the making of subjective decisions during the triage process, which throws into doubt the reliability of the overall SRI scorings.

The SRI methodology has been criticized for yielding inconsistent outcomes for the same services or technical features in different buildings [26,29]. According to our study, the current triage method results in a building specific classification system, which only allows comparison among buildings in which similar SRT have been implemented. It is questionable whether such an approach supports the original aim of SRI as an EU-wide energy efficiency activity [1]. What is a sufficient level of smart readiness when the scoring does not specifically express the baseline for the classification? We introduced a parallel methodology—triage B—for completing the selection of the applicable services, which would compromise between comparability and relevance. In triage B, the assessor would omit only those services from the SRI service catalog that have not been implemented in a building due to a parallel service listed for the same function. An example of such case would be heating-2a and heating-2b, where both services represent the same function—heat generator control—in the SRI service catalog. On contrary those services, which could have been implemented on the site but were not realized therein due to a resource limitation, for instance, would be part of the assessment after triage B. However, because the rules for deciding which services are relevant for a given property are up to interpretation, different assessors could obtain different results. The implementation of triage B would, thereafter, require strictly regulated rules for the SRI relevant service selection process.

In this study, we demonstrated that the comparability of the case buildings increased when the chosen number of applicable smart services was close or equal to the maximum number of SRI services, instead of triage A based on the selected number of applicable services. Additionally, the SRI scores seemed to more consistently follow the current energy performance classification system (EPC) score when the case buildings' numbers of selected applicable services were not reduced. The current EPC classes varied from A to E with the assessed case buildings. Nevertheless, the smart readiness score for all case buildings was D according to the SRI ranking scale [19] after triage A. This finding raises the question of whether the current triage process methodology supports the national EPC goals as it was initially outlined in the revised EPBD [1]. Because both the SRI and EPC are mandated under the EPBD, it appears reasonable to assume that the SRI aims to complement the national EPCs [30,31].

From a practical point of view, the influence of the triage process seems to be undeniable on the applicability of the SRI. To improve the applicability of the framework, it will become highly important for the methodology to differentiate, for instance, between a service that is not applicable because of a parallel SRT implementation and a service that has not been implemented due to a resource limitation. It is overall questionable whether the SRI framework should even allow such subjective decisions to be made during an SRI assessment and whether one indicator is even capable of providing an equally applicable classification system across Europe.

There are some limitations to this study. A more fundamental analysis regarding the applicability of the SRI to cold climate countries would demand a greater sample of buildings, preferably with a wide geographical scale and multiple applicable heating supplying methods. The case buildings utilized in this study, however, were a good representation of the building stock in a cold country metropolitan region, where the technological implementations are strictly regulated. In the case assessments, we applied the streamlined version of the smart ready service catalog. In future studies, it would be valuable to apply the full-fledged smart ready service catalog and examine its applicability to cold climate countries. The subjective experience—which was applied in the analyses of the triage process related methodology—was considered valuable, especially in the context of supporting the development work of the SRI's second technical support study.

6. Conclusions

This study was set to provide the first insights into the applicability of the smart readiness indicator (SRI) in cold climate countries. In the recently revised Energy Performance of Buildings Directive (EPBD), the SRI was presented as an energy efficiency activity to support the uptake of smart ready technologies (SRT) in the building sector. To realize its original purpose, the SRI framework should be equally applicable over all climate regions in the European Union (EU). In this study, we analyzed the SRI's applicability in cold climate countries, where significant energy efficiency potential exists but the market specific technologies might vary significantly compared to the baseline design for European SRI. In this study, we applied the SRI methodological framework and the streamlined version of the smart ready service catalog from the final report of the first SRI technical support study.

In this study, we found that the baseline design for the European SRI is not directly feasible for cold climate countries. Without any methodological changes in the framework, the SRI appears not to realize its original purpose as an equally applicable EU-wide energy efficiency activity. To improve the applicability of the SRI to cold climate countries, the full-fledged smart ready service catalog could be applied as the baseline for developing a cold climate country specific framework. Additionally, the applicability could be improved by reconsidering the realization of the selection of the SRI relevant building services (i.e., the triage process) in practical experiments. One proposal could be to exclude the opportunity for subjective decisions in the triage process.

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