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Big data and data sharing in the AEC: Stakeholder priorities, opportunities, and perceived barriers

Teknologi for et bedre samfunn

SINTEF Rapport
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Construction City Cluster

Construction City is a business cluster that works to consolidate the competitiveness of the construction, civil engineering and real estate development sector in Norway. We have almost 100 members, varying from promising start-up companies to major entrepreneurs. Together we share knowledge and find new solutions on behalf of an entire industry.

The construction, civil engineering and real estate development sector in Norway is currently a world leader in terms of its use of digital tools but is failing to apply cross-sectoral systems that have real and effective impacts on efficiency and competitiveness. According to Statistics Norway, there were 4.2 million buildings in Norway in 2020. Most of this building stock consists of structures built before the digital age, and many of the newer buildings have been constructed with their data sources locked inside inaccessible, specialist and proprietary digital tools.

Construction City wants to address this issue. Single-company data strategies address the value of data and the need to share, but often lack enabling mechanisms for access to essential data expertise and data management processes. For users, this means poorer service, and systems that are less tailored to individual needs. For wider society, it means that we fail to make the optimal use of our building stock. We believe that more learning and smarter operation of buildings may result in a need for less space per user and better energy optimization, leading in turn to an enhanced perception of building quality. The sharing and reuse of data will also provide opportunities to promote innovation in the construction and real estate development sector. Standards must be adapted to the needs of our industry, but at the lowest possible levels of complexity. Voluntary and more open industry standards can be the basis for cost-effective and scalable solutions. Norwegian companies have the opportunity to take the lead in developing such standards in areas where they hold a strong position. Construction City wants to promote the formation of a major ‘community’ that will facilitate a system of expertise and solution sharing, rooted in experience from both Norway and overseas.

Introduction

This report aims to present the results of a research project carried out with different stakeholders in the Norwegian real estate market, investigating the potential of using Big Data as an asset in the operational phase of buildings. In two workshops, 80 participants reflected on their current data sharing and management practices. They were asked to identify the information they would like to obtain through better analytics, key performance indicators and shared data, and the perceived barriers to using Big Data in their organizations. These findings are complemented with an overview of key performance indicators described in academic research for different stakeholders and examples of framework proposals for data-enabled facility management and data integration architectures. Finally, examples of information showcased in existing IT platforms to collect and visualize data through dashboards are also provided.

Stakeholders

Priorities

The first step to defining how Big Data and shared databases could be used as an asset and a way to create value for the stakeholders represented in this project was to outline their priorities. These were: to increase tenant satisfaction, to increase operational efficiency and to increase sustainability.

Tenant satisfaction

Efficient operation

Sustainability

The next step in developing a common structure for a shared database was to identify the main categories of inputs and outputs that the stakeholders involved in the project would like to include. This was schematically presented as a system with four components: inputs, outputs, the “system” or the shared data knowledge base, and the external factors that would influence outcomes (Figure 1).

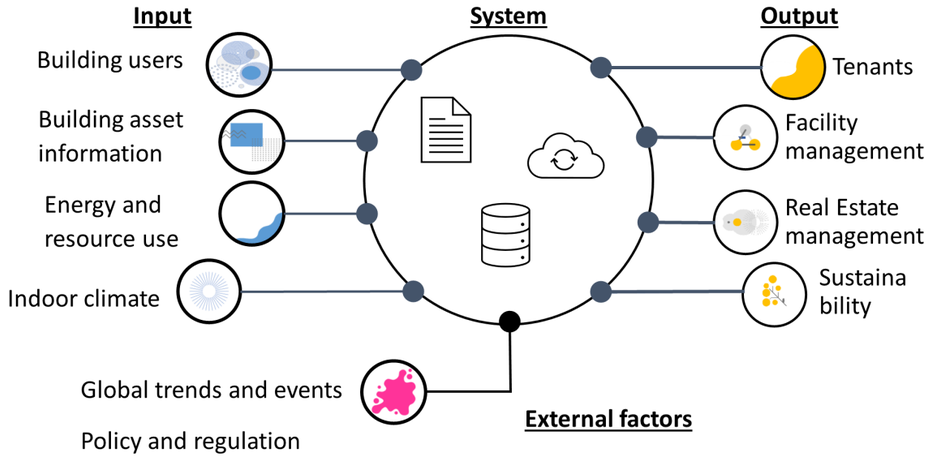


Figure 1: 1 The overall simplified architecture of a system for shared data

Each category’s contents with its respective sub-entries were identified through a live voting session with the stakeholders. For the primary input, stakeholders first chose to focus on tenant centric information, which was in line with their main priority, i.e. tenant satisfaction (42% of votes). The second category was asset use information which includes the second priority but extends the topic to asset management possibilities (19% of votes). The third input category was energy and resource use (19% of votes), which embodied the third priority previously defined. The fourth category identified related to indoor climate parameters and received 19% of votes. For the output categories, the stakeholders involved voted for the following four categories: tenant or end-user 20.8%, facility management 20.8%, real estate management and asset portfolio 20.8%, and sustainability 32.1%. Similarly, as for the input categories, the participants were also asked to specify sub-categories. These are shown in Figure 2.

Finally, the partners were also asked to identify external factors that they considered the most impactful on their buildings’ operation and for which they lack insight. The idea was that these factors could be used as the basis of scenarios for simulations of how well a stakeholder’s portfolio or single asset would fare in different situations. The benefits of such analytics are plentiful. For example, they could help define actions to mitigate risks, support insightful investments, and outline opportunities and weaknesses in an entirely new way. Here three main categories of factors were outlined: global trends and events (52.9%), changes in policy or regulations (29.4%) and climate change or natural disasters (17.6%) (Figure 3).

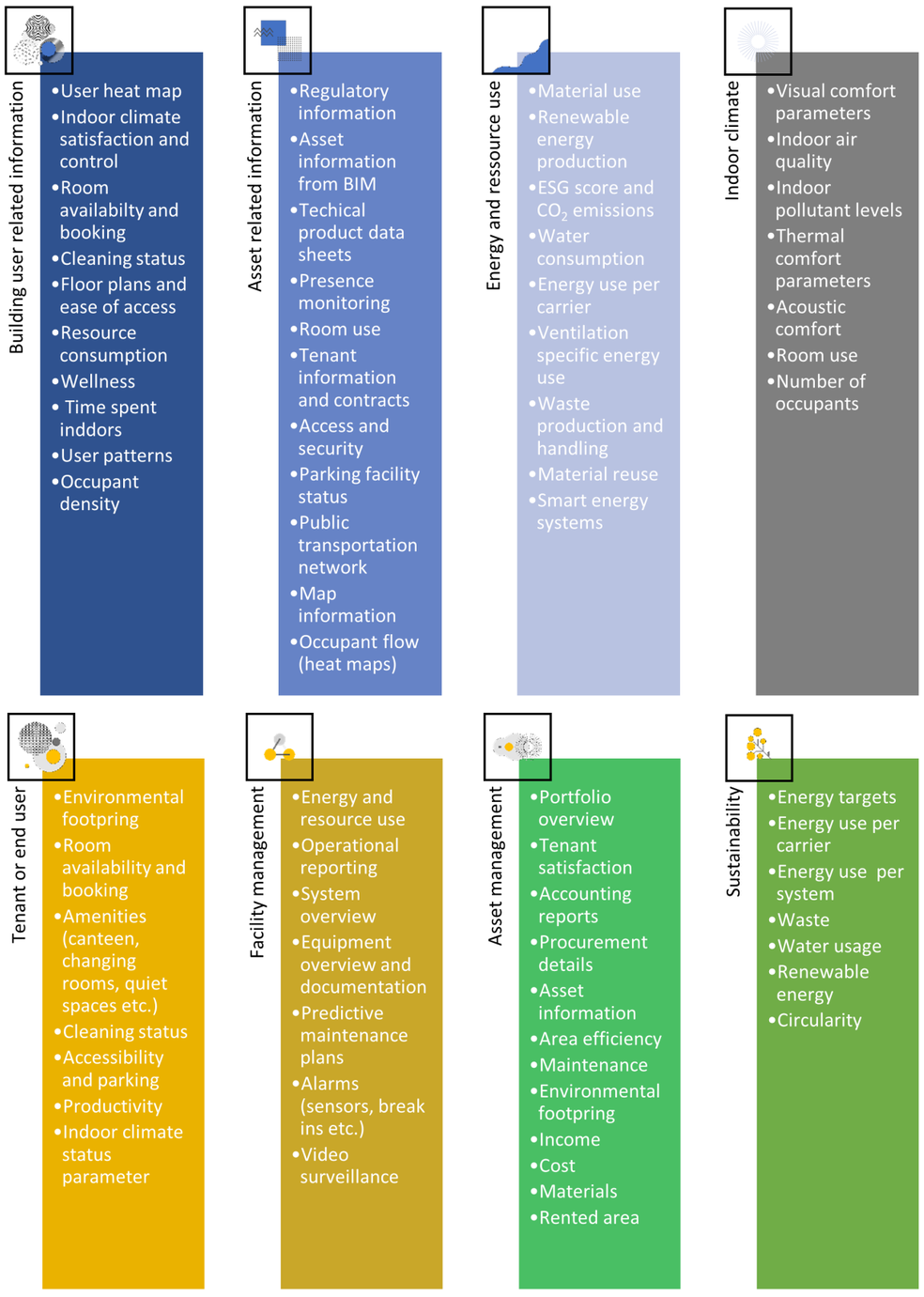


Figure 2 Main and sub-categories for the inputs and outputs of the system defined

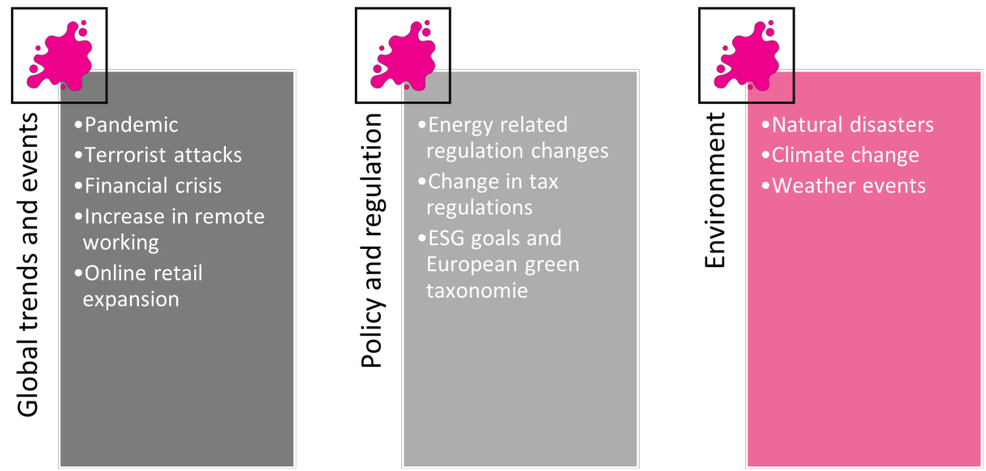


Figure 3 External factors that impact building operation and real estate as defined

How to measure performance?

Given the three priorities outlined by the project's stakeholders, we present a review of some of the key performance indicators (KPIs) reported in academic literature and used in environmental certification schemes.

Tenant satisfaction is often measured and benchmarked through post occupancy evaluations (POE). The goal of POEs is to capture the actual occupants' actions and experiences to understand how people use buildings. POE are human-centric evaluations as opposed to technical evaluations carried out in commissioning phases. The KPIs used in POEs depend on the building's category since users have different needs and expectations depending on how they use the facility. For example, in offices, POEs tend to measure workers' comfort and productivity. In residential buildings, they are commonly used to qualify the resident's experience regarding the use of shared facilities. In healthcare buildings, they evaluate accessibility/ wayfinding from the perspective of staff, patients, and visitors or check the compliance of strict indoor environmental quality levels. In retail buildings, the most common topic for evaluation is shopper behavior and movement patterns. This is a key difference from other building-in-use evaluations focused on other building performance aspects, such as structural, financial, or mechanical systems assessments. Although KPIs defined in POEs cannot directly be translated into inputs or outputs, they can provide insights into how to increase tenant satisfaction and the factors that matter. In the table below, we have listed possible performance indicators and types of information that could be used in a common database defined by POEs,

Main KPI categories and information required for tenant satisfaction	Main KPI categories and information required for improved operations	Main KPI categories and information required for increased sustainability	Ref.
<u>Ambient environmental related requirements</u> Biophilic design Air quality Acoustic comfort Air temperature Air velocity Ventilation rates Quality of lighting and access to daylight Cleanliness of spaces Perception of safety through design and through personnel <u>Spatial environmental related requirements</u> Accessibility Quality of elevators and stairways Parking Ease of wayfinding Natural meeting points Workspace organization and flexibility (cell offices/ open plan seating/meeting room) Quality of amenities (canteen, shower, changing rooms) <u>Communication and feedback procedures</u> Fire safety procedures Waste disposal procedures Room booking and availability Complaint processing systems Feedback channels <u>Technology related requirements</u> Quality of Wi-fi and connectivity Access and security User interface with systems	<u>Functional performance evaluation</u> Strategic value Aesthetics and image Space Environmental comfort aspects Amenity Services and equipment Serviceability Operational cost Life-cycle cost Operational management <u>Technical performance review</u> Physical system Environmental systems Adaptability Durability <u>Building infrastructure – geometric information</u> Site information Component information Decorative and exterior enclosure products' information Facility information (HVAC, electrical, mechanical, pumping) Location information <u>Building infrastructure – non-geometric information</u> General building and infrastructure information Facility information (e.g., building services) Organization information Cost information Guidelines and specifications Maintenance information Manufacturer, contractor, and vendor information Resource planning information Facility Management information Energy and living environment information Emergency protection information Inventory information Income from operations <u>Real-time information</u> Occupancy evaluation (density, distancing, spatial distribution, trajectory, speed, permanence) Heat maps Customer/ user flows Length of stay CCTV Feed Alarms	<u>Materials</u> Low environmental impact Low VOC emissions (volatile organic compounds) <u>Energy use</u> Renewable energy production Electric energy storage Thermal energy storage Building Primary Energy Energy use per carrier <u>Greenhouse gas emissions</u> CO2 emissions for the asset arising from the fuel and electricity consumed by the asset, business travel of personnel based at the asset and transport of goods despatched from the asset during the reporting year. <u>Water consumption</u> Total water consumption Greywater <u>Waste management</u> Total waste production Percentage of waste recycled <u>Transportation</u> Facilities to promote biking Closeness of amenities Public transportation proximity <u>Land use & ecology</u> Green areas on site Biodiversity Contribution to ecology or biodiversity	[1]–[6]

Table 1 Key Performance Indicators used and defined in academic studies to measure the performance of buildings with regard to user (tenant) satisfaction, improved operations, and sustainability.

Data brokers, shared databases, and IT-FM architectures

Data brokering is an established market within the building industry where standard real estate information is sold to platforms that provide services to their clients. This market exists both for commercial and residential real estate. However, these are primarily focused on investment, where parameters such as vacancy, rent growth, and exit values are central to the financial analysis. Most of the existing databases are paying, standalone services that do not share data. The information they contain concerns both the properties and the tenants with standard information such as building year, size, rent or sale comparable data, ownership details, lease information and specific analytics based on traffic counts and demographics.
The structure of the database discussed in this project would go beyond the types of datasets used in these multiple listing services software and would include more detailed data about building structures, ownership, inhabitants, technical systems, sensors, events, and more. According to the Swedish initiative to build such a database, the Real Estate Core project [7], sharing data formatted in a common ontology allows property owners to connect their buildings with new services on a large scale. It also avoids issues relating to the building- or technology-specific implementation details and formats.

Shared databases that can contain the information needed to improve how buildings are operated must also evolve and integrate new approaches to collecting data or perceiving data, carrying out actions and learning from the intersection of different system layers. To shift facility management (FM) systems from static repositories that are time-consuming to update to dynamic systems that support “cognitive” buildings, the sensing architecture in the buildings needs to be upgraded. This is a crucial step in developing facilities that can learn from and integrate user demands and feedback or which can use digital twin versions of themselves to improve their operations.

There is currently an unprecedented explosion of sensor and spatial data being generated in the building industry. The Internet-of-Things (IoT) and building and energy management systems (BMS/EMS) are becoming commonplace in modern commercial buildings while building information models (BIM) capture geometric and metadata from the design phase. Yet, these temporal and spatial data are highly underutilized. This is mainly due to their heterogeneity, which makes it difficult to apply traditional analytics or to easily create standardized structures and shared ontologies for databases containing the information. This includes processing a lot more inputs from sensors and input from users and facility managers. A detailed example of such an infrastructure architecture is shown in Figure 4 based on the work of Xu et al. in 2019 [6].

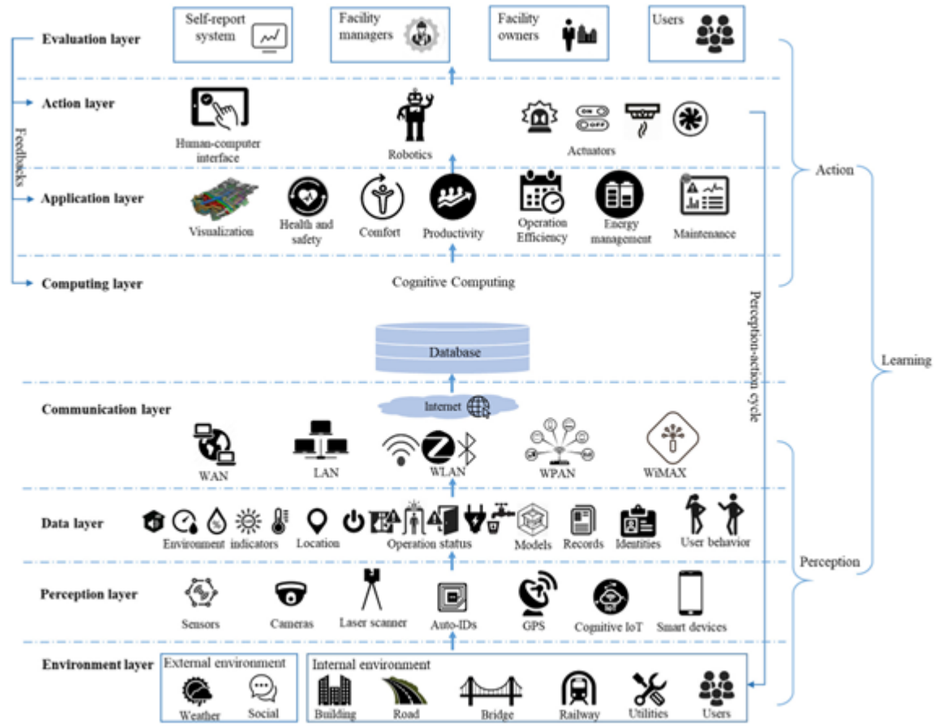


Figure 4 FM system architecture for a “Cognitive Facility Management” system, as described by Xu et al. 2019

Current barriers to data sharing

Collecting data in a shared database and using big data could allow uncovering new insights into how to create value for tenants, as well as help maintain and manage attractive and sustainable buildings while supporting benchmarking through standardized KPIs. In this project, four main types of challenges were identified.

Technical challenges
The most common technical challenge reported was by far the lack of standardization of data. This challenge relates to being able to store and compare equivalent data sources for different actors using the common database. Associated with this challenge is the topic of metadata and having common descriptors that can allow interpreting the data and putting it in context. Data cleaning, siloed data, data security, poorly designed APIs and lack of business models were also named as current technical challenges.

Cultural challenges
Challenges relating to data sharing culture were also considered to be one of the most critical barriers to data sharing. This time, the fear of change and data hoarding were named as key issues. Other elements that the stakeholders saw as cultural challenges related to shifting to more innovative business cases and mindsets to develop more substantial incentives to share data as well as a grounded understanding of the value of shared data within the industry.

Business challenges
The most important challenge identified in terms of business models for shared data concerned data ownership. It was also pointed out that most stakeholders had little experience with business models connected to big data. The lack of experience and technical knowledge makes it difficult to understand the financial value of data sharing for building owners and for tenants. There are no known demonstration projects which could be used as a starting point and which could provide best-practice insights in relation to value creation.

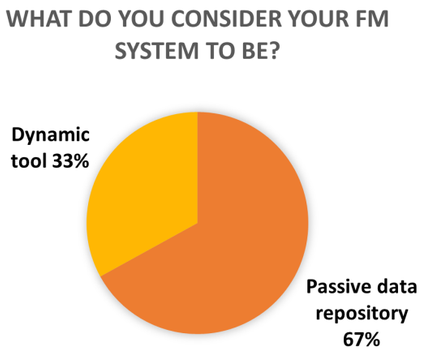
Regulatory challenges
The fourth type of challenge identified in this project pertained to regulations and laws for data sharing. The most important concern in this regard was the trading of personal information and GDPR regulations. There are also currently no standard contracts to define how one can collect, store, share and use data. This lack of regulatory infrastructure is a major challenge for building owners and consolidates previously mentioned barriers that related to the reluctance to share data, the lack of knowledge and concerns about the absence of proven business models with clear financial and social outcomes.

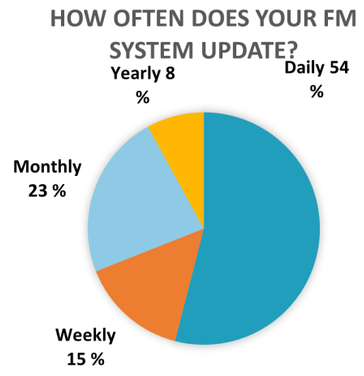
FM systems of today and tomorrow

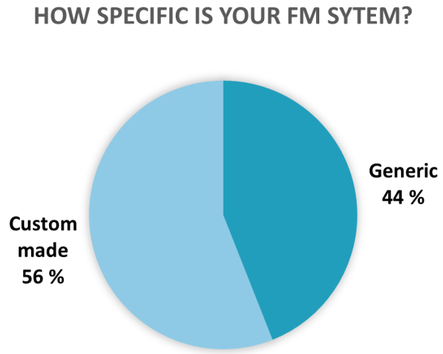
This project also aimed to inquire about current practices that the stakeholders had regarding their facility management systems or the platforms they used to collect data. When asked about the level of customization of the tools used, 56% of the respondents considered their system to be custom-made for their needs, while 44% reported having a generic system. However, a large majority of the partners involved (67%) said that they used the system as a passive repository, while only 33% considered it to be a dynamic tool.

The stakeholders surveyed in this project estimated that the external factors that had the most impact on how they operated building today were the level of knowledge they had, the patterns in which buildings are currently used - which today are highly impacted by the COVID-19 pandemic-, financial aspects, climate change related policies and the increase in digitalization. When asked to look at a five-year horizon, they expected that the most important factors in 2025 would be energy prices, lower revenues, the emergence of new digital platforms, technologies and business models, climate change related ESG policies and requirements, and most importantly, higher expectations and demands from tenants.

Although there are overlapping elements in the answers to the two questions (the threat of climate change), it appears that the drastic changes brought upon by the COVID-19 pandemic have consolidated the realization that physical offices were not as necessary as previously thought. This means that tenants that opt to return to physical offices have higher expectations about the quality of the facilities they choose to rent. This can be seen, for example, in the dramatic increase in demand for green or healthy building certifications since December 2020 [8]. The stakeholders that took part in this project have anticipated this and expect a certain level of disruption in their business models. This is also evident from the initial survey about priorities where satisfied tenants came up as the most important topic.







Conclusions and further opportunities

This pre-research project was carried out with different stakeholders in the Norwegian real estate market, who all agreed on the significant potential of data sharing in the operational phase of buildings. Addressing the digital transformation of the built environment requires more extensive involvement of all players across the built environment value chain and throughout the building life cycle. Luckily, several funding opportunities for research and/or innovation are available to both the industrial sector and the research sector. Both SINTEF (the largest research organization in Norway) and Construction City Cluster (a vibrant cross-sector community of people and companies willing to change the face of Norwegian construction and real estate) wish to take an active part in solving this complex challenge and welcome any expression of interest for future collaboration within one or several research- or innovation projects. A selection of calls relevant to data sharing for buildings is listed below and summarized in Table 2.

➔ The Research Council of Norway (RCN) is regularly publishing calls under the denomination “Collaborative and Knowledge-building project” (KSP) with the aim of generating new knowledge needed by the industry to enhance innovation and sustainable value creation. These research projects shall stimulate and support cooperation between research groups and companies in the building, construction and real estate industry.

➔ The Research Council of Norway (RCN) is also providing grants to business-led innovation projects that make extensive use of research and development activities under the denomination “Innovation Project for the Industrial Sector” (IPN) and “Innovation Project for the Public sector” (IPO). An Innovation Project shall lead to renewal and sustainable value creation for the project’s business partners and shall also generate socio-economic benefits by making new knowledge and solutions available.

➔ Innovation Norway (IN) contributes to sustainable growth and exports for Norwegian business through capital and expertise. Innovation Norway provides grant for financing innovation and development to projects where the socio-economic benefit is considerable, and the technical risk is high. The most common grant schemes are linked to environmental technology, innovation in collaboration and more environmentally friendly use of bio-resources.

➔ Horizon Europe (EU), the EU’s ninth framework programme for research and innovation, was launched on January 1st, 2021 with a total proposed budget of EUR 95.5 billion. Norwegian actors can apply for funding on equal footing with enterprises, public sector bodies and research institutions in EU member states.

Funding body	Project type	Specific topic	Deadline	Project owner	Available budget *[MNOK]*
RCN	KSP	Digitalization of building process	May 2021	Research institutions	50
RCN	IPN	Broad thematic areas	Open-ended/2021	Companies	1300
RCN	IPO	Selected thematic areas	September 2021	Public sector body	TBA
IN	Innovation project	Selected thematic areas	Open-ended/2021	Companies	N/A
EU	Innovation Action	Advanced data-driven monitoring of building stock energy performance HORIZON-CL5-2021-D4-01-03	N/A	Any type	100
EU	Innovation Action	Industrialization of deep renovation workflows for energy-efficient buildings HORIZON-CL5-2021-D4-01-02	N/A	Any type	160
EU	Innovation Action	Demonstrating integrated technology solutions for buildings with performance guarantees HORIZON-CL5-2021-D4-02-01	N/A	Any type	150
EU	Innovation Action	Demand response in energy-efficient residential buildings HORIZON-CL5-2022-D4-01-01	N/A	Any type	120
EU	Innovation Action	Renewable-intensive, energy positive homes HORIZON-CL5-2022-D4-01-02	N/A	Any type	120
EU	Innovation Action	Smarter buildings for better energy performance HORIZON-CL5-2022-D4-01-03	N/A	Any type	120
EU	Innovation Action	Smart-grid ready and smart-networkready buildings, acting as active utility nodes HORIZON-CL5-2022-D4-02-04	N/A	Any type	180

Table 2. Funding opportunities in 2021 and 2022

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