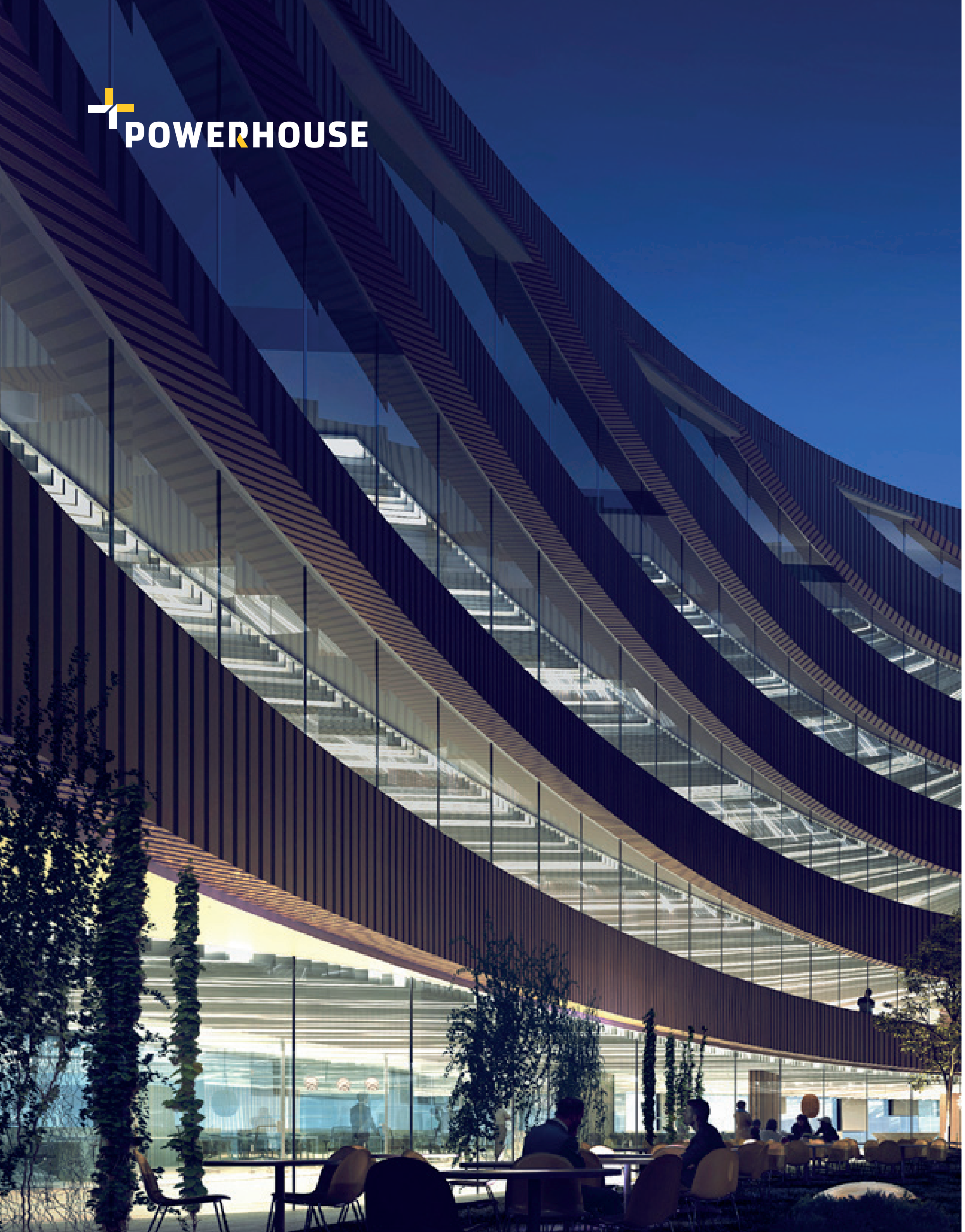

Smart by Powerhouse

Guide for resource-efficient and functional commercial buildings

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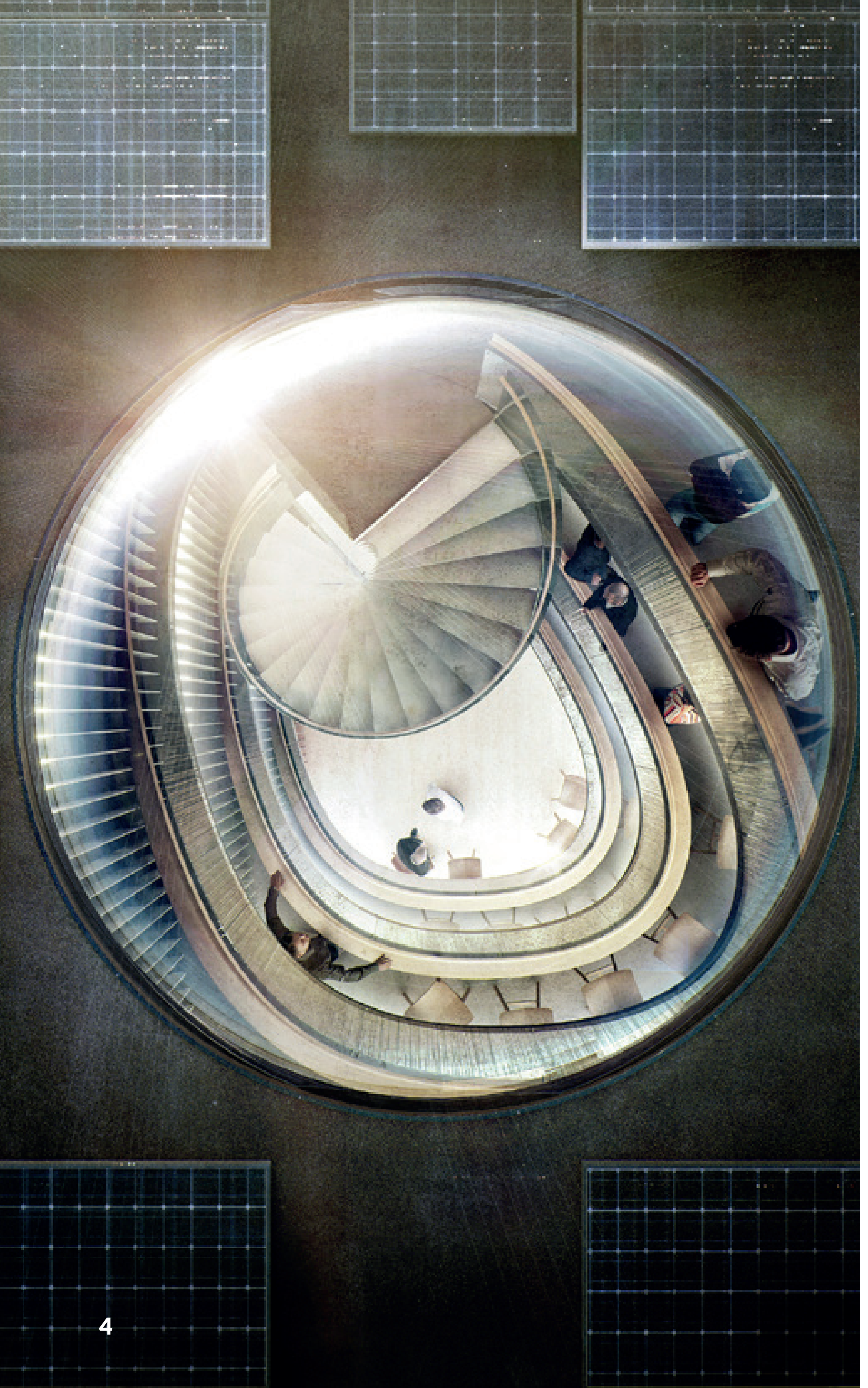


1 Preface

This guide has been prepared by the Powerhouse collaboration consisting of Entra, Snøhetta, Asplan Viak, Skanska and the environmental organisation ZERO, with support from market players in the construction and real estate industry as well as technology and IT companies that supply products and services to smart buildings. The Powerhouse collaboration would like to thank everyone who has contributed with constructive questions and input in this work. Special thanks go to the Research Centre on Zero Emission Neighbourhoods in Smart Cities (FME ZEN), led by Sintef and NTNU, for valuable contributions to the development of this guide.

Enjoy the read and good luck in developing future-proof buildings!

SKANSKA asplan viak ZERO entra Snøhetta

2 Objective of the guide

Focus on smart buildings is on the rise. Interest among owners and tenants is growing, and market parties are making strong commitments to developing products and services, and to promoting their solutions. Several buildings featuring extensive use of smart technology have been realised, and many more are being developed. Even so, the industry lacks a framework for creating a good dialogue and discussion about the need for and anticipated effect of smart technology in buildings. The objective of Smart by Powerhouse is to facilitate this dialogue, and the guide is freely available for market parties in the sector who recognise the benefit of a functon-based framework to achieve resource-efficient and functional buildings.

Technology is at the heart of the guide, but the use of technology is not an objective per se, only a means to an end. Deliberate and targeted use of technology will yield an enhanced user experience and productivity, a lesser environmental impact, reduced operating costs and increased adaptability to meet future needs.

The scope of opportunity for smart buildings will change as new technology is gradually developed and becomes commercially available. *Smart by Powerhouse* is therefore a dynamic guide that will address new solutions, ideas and contributions from the sector through new and improved editions. The objective of sharing the guide freely in the sector is that the next version will be more tried and tested, and with even better quality than if it were reserved solely for the Powerhouse collaboration.

Today, in parallel with this technological development, we see increased pressure on the earth's resources and the state of the climate. The future will bring new demands. One of these will be that we build more environmentally sound and climate-friendly buildings than is the case today. The Powerhouse collaboration has ambitions to realise buildings where the total lifecycle greenhouse gas emissions comply with the requirements set out in the UN climate report [1] and the 1.5-degree goal. This has been called *Powerhouse Paris Proof* [2]. While the environment is one of the effects the guide focuses on, there are many different aspects within environment and climate that are not addressed, such as use of materials. These aspects are equally important if the ambition is to build to achieve the 1.5-degree goal.

3 Application and scope

Smart by Powerhouse is a tool that can be used for design, development and communication of smart commercial buildings, both new constructions and rehabilitation projects. With just a few adjustments, the guide can also be used for purposebuilt public buildings such as cultural buildings, schools and childcare centres. It defines the smart commercial building concept, and specifies the effects and values viewed from the perspectives of the building's users, tenants, owner and society in general.

Achieving these values will depend on the chosen level of ambition. The guide lists five ambition levels, where the current building standard is the basic level (level 0)[1]. The guide also presents five key topics within smart commercial buildings, each with a set of functional requirements[2]. The complexity of each functional requirement increases as one moves up through the ambition levels.

Ambition levels

0 Automated
1 Smart ready
2 Smart standard
3 Smart predictive
4 Smart cognitive

Topics

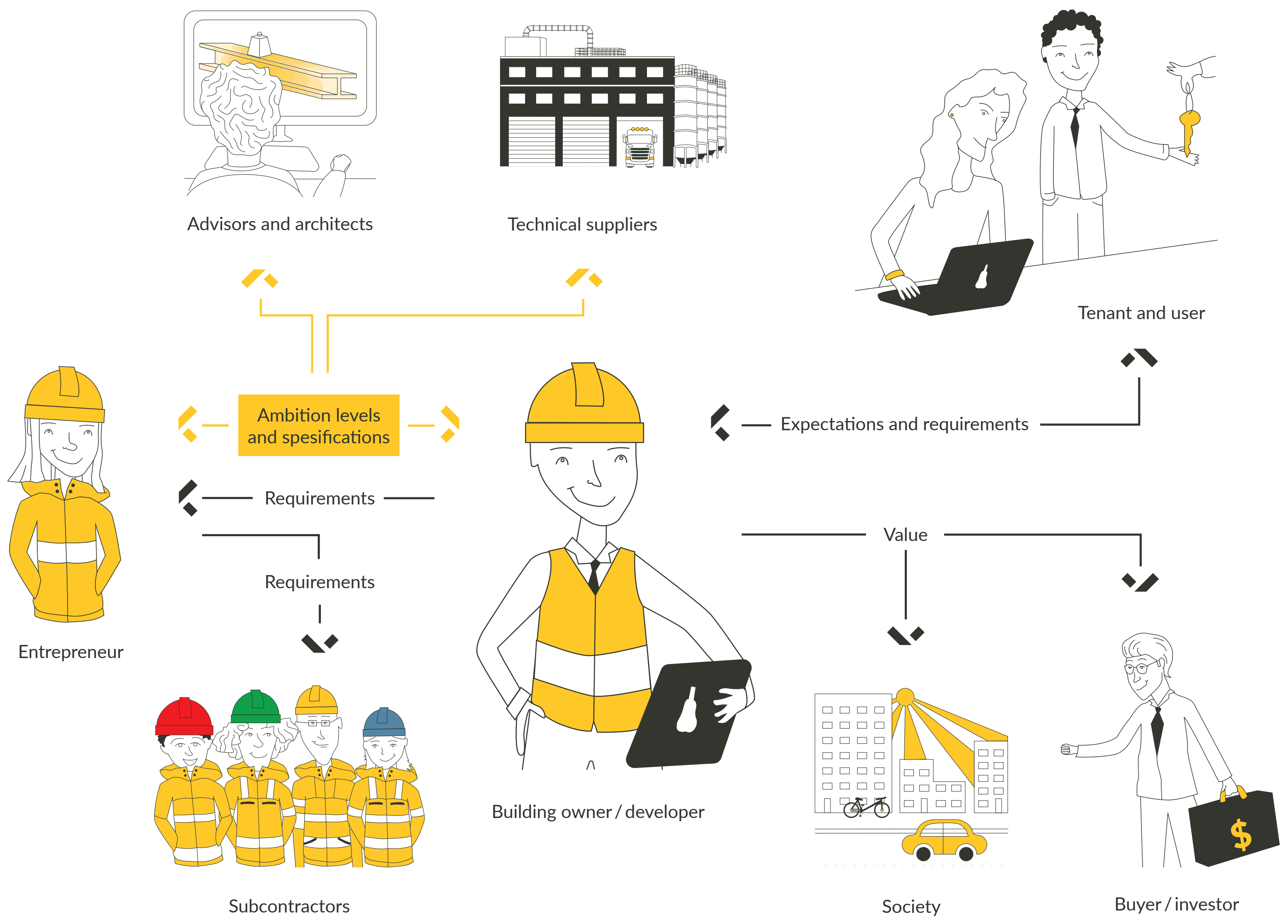
Enabling technology
Indoor climate and working environment
Energy and resource utilisation
Safety, security and reliability
Adaptivity

The guide enables market players in the value chain to discuss the interplay between technology and desired value, to set ambition levels and assess the possibility of achieving these values. In a more detailed perspective, it could be useful for:

- assessing value viewed from the perspective of expected and future users
- guiding expectations through clear, concrete dialogue between building owner and tenant
- discussing ambition level and specification of smart technical installations
- contracting with architects, consultants, developers and technical suppliers
- documenting and communicating the building's technology level
- estimating the value of buildings with smart technology

On the other hand, *Smart by Powerhouse* is not a requirement specification as a basis for certification, with the associated verification and documentation requirements.

It should be noted that *Smart by Powerhouse* does not provide advice or guidance (explicit or implicit) as to how owners and tenants shall ensure that personal information is handled in accordance with prevailing legislation, including the EU's General Data Protection Regulation 2016/679 ("GDPR") [3] and in current privacy legislation that implements the GDRP. All handling or processing of personal information outlined in the guide must be subjected to a concrete assessment in each individual case.



The guide is a tool for stakeholder groups in their dialogue concerning expectations, ambitions, requirements and value.

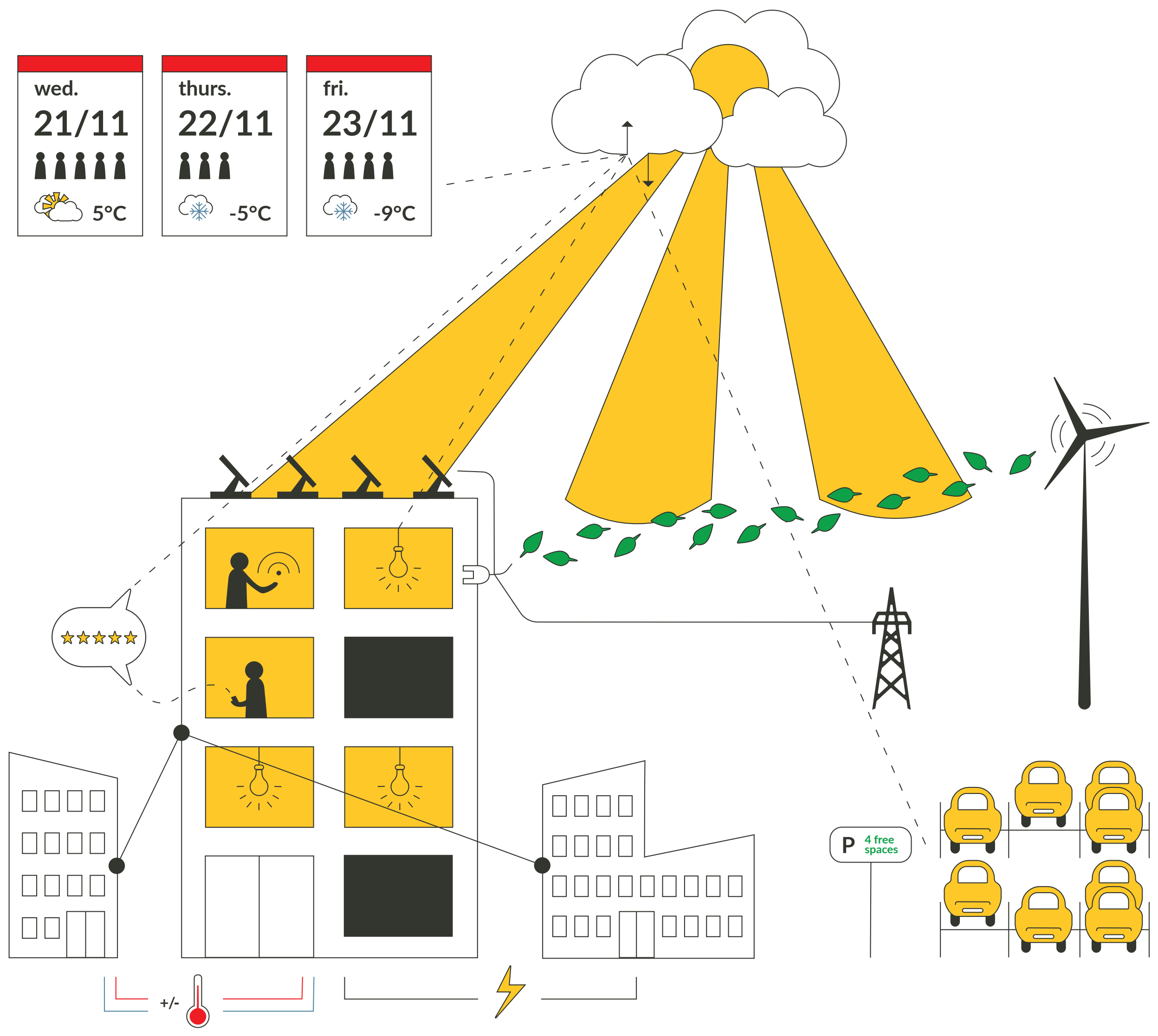
[1] See Chapter 6 for more information about ambition levels
[2] See Chapter 7 for description of topics and functional requirements

4 Definitions

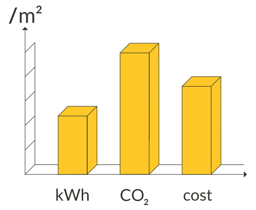
A smart building is characterised by comprehensive technological solutions, where attempts are made to balance various conflicting goals in order to achieve a building that is futureproof, environmentally sound, cost-efficient in both procurement and operation, and safeguards the primary stakeholders' expectations and needs.

Primary stakeholders include users, tenants, owners and society in general. A *Smart by Powerhouse* building enhances stakeholder value by:

- using architecture, design and technology in harmony, as a means of creating functional rooms and efficient floor space
- realizing added value for stakeholders through comprehensive and needs-based use of technology
- being prepared for and equipped with technology and infrastructure that increase the building's future value for user, tenant, owner and society



A Smart by Powerhouse building safeguards the user, the environment and society at large through comprehensive application of smart technology.



	User satisfaction	Environment	Efficient floor space	Robustness
User	Well-being, health and satisfaction	Making a positive contribution to the environment	Smart solutions and functional spaces	Simpler everyday life
Tenant	Increased employee productivity	Wise user behaviour and smaller climate footprint in operation. Good reputation.	Reduced rent costs (more for the money)	Flexibility when needs change
Owner	More attractive in the market	Smaller environmental impact, reduced risk and good reputation	Higher rental income per square meter	Future-proof, flexible buildings and increased property value
Society	Better public health	Reduced use of resources and environmental impact	Increased value creation	Equipped for changes in climate and environment

The desire for added value through comprehensive and needs-based use of technology is a shared goal for users, tenants, owner and society, but the desired effect and technology preferences will vary among the same stakeholders. For example, one owner would focus on applying technology that can increase capacity utilisation, and thus building revenues, while the users will not necessarily perceive this same technology as creating value for them. This and other similar conflicting goals must be examined and balanced in the development of smart commercial buildings. As discussed, the expected effects of a *Smart by Powerhouse* building will vary among the stakeholders, but on a general basis, the key effects can be divided into four categories: user satisfaction, environment, efficient floor space and robustness (see table).

5 Development process

Achieving truly effective use of technology in buildings requires setting the ambition level from the very start, insofar as possible. This choice is crucial as regards detailing qualities, which in turn guide the design phase. The building owner must undertake assessments as regards his own ambition level and the expectations of potential tenants.

Cost-benefit assessments should also be performed, where costs and expected effect are weighed against the value one expects to achieve in the market. Costs associated with later upgrades in connection with switching tenants should also be considered. As an aid in determining the correct level of technology use, the building owner's perspectives regarding the following questions should be reviewed:

- need for flexible spaces and what type of flexibility the building will offer
- anticipated number of tenants and lease terms
- market expectations for smart technology in buildings
- whether relevant tenants have desires concerning specific technical solutions
- whether the building will be operated by the owner, or will operation be subcontracted out; if so, what will be subcontracted
- what services in the building can be streamlined and digitalised, e.g. cleaning, parking, cafeteria, conference room booking, etc.

Flexibility and active space utilisation

Shorter and more flexible leases challenge the building owner's need for predictability as regards how to plan and facilitate space and technology. Well-planned robustness in areas and floor space plans, that does not come at the expense of initial user quality, may be a measure for employing the rental space over a larger part of the lifecycle. Supported by various technologies, one can activate rental space for larger parts of the day / week / year through shared use or multi-use.

This is easier to accomplish with a goal and a plan starting as early as in the design phase. It is therefore important to consider what multi-use options lie in nearby buildings and neighbourhoods in the early phase of project development. No one knows for certain which market, which tenants, which technology and financing the future will bring – but it is possible to make the building more or less prepared, flexible and robust for the unknown.

Early design phase

Regardless of contract format, it will be useful to bring ambitions regarding technology use into the discussion with architects and consultants. To highlight and deal with the interfaces between building, technology, operation, user and society, it is important that the parties work together, involving as many stakeholders as possible, to clarify overall needs and expectations. One sensible solution may be to bring in external support, for example an independent ITB / ICT advisor who can facilitate a process with the goal of determining the ambition level. With the selected level of ambition as a starting point, the developer can then add or delete functions that are expected to add to, or detract from, the value of the building.

Detail engineering phase

Once the ambition level is clarified, including potential adjustments, the next step will be to involve suppliers to provide input and comments regarding different solutions that fulfil the desired functions. It may also be relevant to adjust the requirements after receiving input from developers / suppliers, with a view to cost-benefit. In any event, focus must remain fixed on the goal and the ambition level set for the building, so as to meet the original expectations. Most concepts and selection of solutions should be resolved in this phase. One should also clarify the extent of tenant adaptations that should be permitted, as technology and solutions could conflict with the objectives and ambition level.

6 Ambition levels

The guide lists five ambition levels or maturity levels for smart buildings (see figure). The guide borrows onceptual ideas from the definitions for autonomous ehicles [4] and facilitates a level categorisation where the basic levels are well-defined. New top levels can also be added over time, without any need to change the basic elements in the guide. The following paragraphs describe what effects the primary stakeholders can expect from buildings that achieve the respective ambition levels.

Level 4
Smart cognitive

Building is self-learning and uses historical data and machine learning to improve its prediction models, operation and management. It communicates and interacts with neighbouring buildings and the surrounding environment.

Level 3
Smart predictive

Building predicts future condition based on direct and indirect data from surroundings and users, makes recommendations or adjusts the building accordingly. Different users receive personal information and guidance.

Level 2
Smart standard

Building communicates with users, provides guidance and/or adapts to the users' preferences and usage patterns. Open APIs simplify sharing of data and implementation of new services.

Level 1
Smart ready

Building has technical infrastructure that makes it possible to develop the building to a higher smart level at a later point in time. Systems that communicate and better access to data simplify operation of the building.

Level 0
Automated

Ordinary automated buildings constructed according to current regulations and statutory requirements.

Ambition levels for smart commercial buildings. The current building standard comprises the basic level (Level 0).

Automated

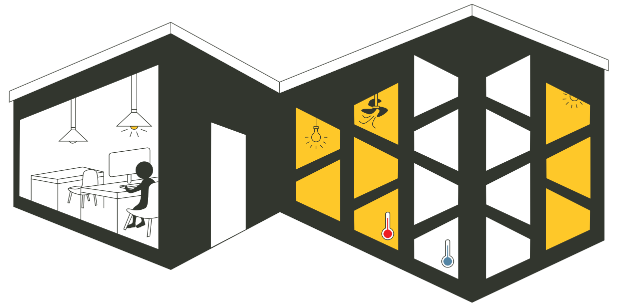
An *Automated* building meets today's high standards for new buildings, including the Regulations on technical requirements for construction works (TEK17), and basic expectations that the various stakeholders have in relation to a building. From a broader society perspective, that means robust and energy-efficient buildings that do not expose the users to significant health-related risks.

At this level, the building owner can expect a building of good quality, with associated low lifecycle costs. On the other hand, tenants can rest assured that the building will have a good working environment where temperature, ventilation and light will be automatically controlled based on predefined levels and hours of operation. The same expectation for indoor climate will apply for each respective user, and they will experience the building as being right for the times.

Smart ready

Neither the users nor the tenants will experience any significant difference between an *Automated* building and a building at the *Smart ready* level. Most of the changes required by this level are in the form of infra-structure and systems in the building that facilitate achievement of the higher levels. Thereby, the owner of the building can expect a building with futureproof technologies installed, which simplifies subsequent integration of new technology and lays the foundation for new services and enhanced user interaction.

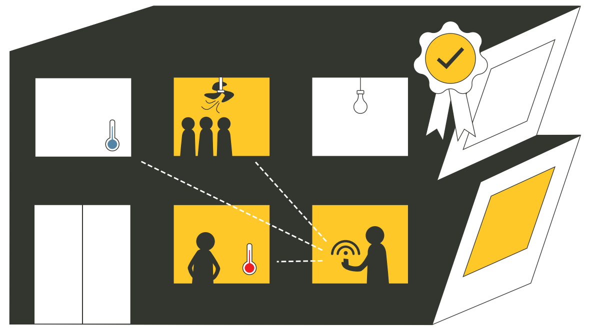
Therefore, the owner can expect the building to hold up better over time, and will have a more extended period in which the building will be perceived as being modern in the rental market, and among users. This thus reduces the risk of future change costs. From a broader society perspective, a *Smart ready* building will primarily yield effects in the form of reduced environmental footprint, as this level places demands on better energy performance and smarter control of heating and ventilation.



Smart standard

In a *Smart standard* building, users can expect substantial differences in relation to the two previous levels. The possibilities for user influence as regards indoor climate will be considerably increased, while users will also benefit from a simpler day-to-day experience in that their surroundings are more geared for automatic adjustment to their preferences. Another example is that users can enter and leave zones based on biometric data. Tenants can expect rental costs that are ncreasingly based on services and follow their individual needs, as well as simpler and better building adaptations as needs change.

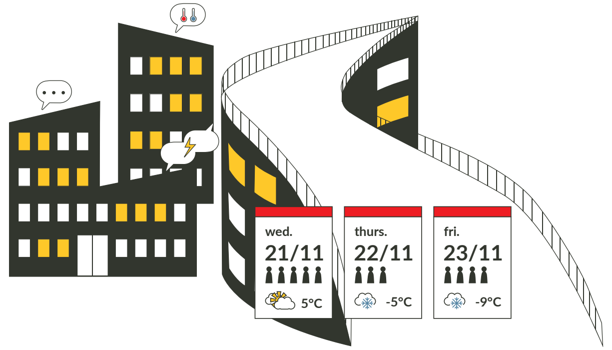
Greater adaptability over the lifecycle can also carry considerable value for the building owner. At this level, the owner can expect a building where the technical solutions are comprehensive and thoroughly prepared with the result that the building, its digital twin and integrated systems ensure more streamlined operations. Finally, society at large will also see effects in the form of lower energy consumption (kWh) for operation, reduced peak loads (kW) from the building and its neighbourhood, increased robustness and new security barriers.



Smart predictive

A *Smart predictive* building can predict the condition of the building and make adjustments based on a large volume of input data. At this level, all of the four primary stakeholders will experience a building that prepares for upcoming operations situations, adjusts itself and/or communicates proposed measures. The building will advise and guide the users based on their own preferences. Tenants, owner and the broader society can expect the prediction models to provide even better energy efficiency in operations, and thus lower operating costs and environmental impact. The building and the neighbourhood will also communicate with outside networks regarding energy needs and grid loads.

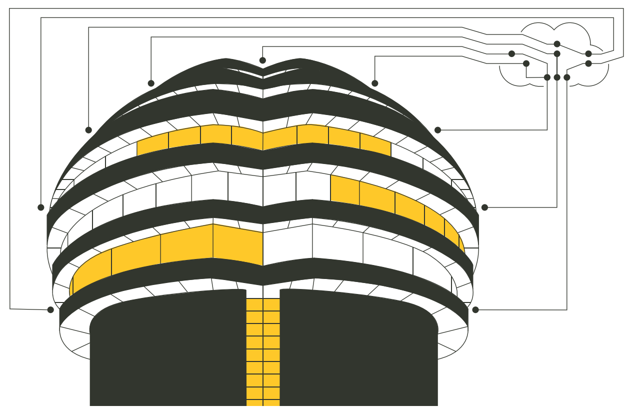
The building will also offer advice in daily operations and suggest fit-outs that yield more active floor space, thus raising the value per square metre for both tenant and owner. The neighbourhood can expect a building that is utilised more fully outside normal working hours, and thus contributes to increasing the quality of the surrounding area. The first commercial buildings that can achieve this level will most likely receive significant attention in the market and in society in general. Both the building owner and tenants can therefore expect to realise an effect in the form of valuable reputation-building and enhanced attractiveness among employees and in the real estate market.



Smart cognitive

A building at this level will exploit large volumes of historical data and machine learning to improve its prediction models and systems, without negatively impacting the user experience. This will improve the building's energy performance, reduce environmental impact and further improve indoor climate; however, this impact will probably be marginal in certain areas. Artificial intelligence will enable the building to predict incidents and events that the building's owner, tenants and users will not necessarily be able to foresee themselves. This feature can increase the experience of quality, or reduce risk, e.g. operational deviations that can be avoided through proactive measures.

A *Smart cognitive* building will ensure high social value throughout the entire lifecycle, as it is able to develop and adapt itself to future needs. While some buildings will meet certain functional requirements at this level in just a few years, significant development work remains to achieve this level for all requirements. The first building that fully achieves this level will be an international sensation.



7 Topics and functional requirements

The smart building concept is undergoing continuous development and the various market players continue to incorporate new topics, functions and effects into this concept [5, 6].
To develop this guide, a group composed of experts in a wide range of fields have arrived at a selection of prioritized functional requirements that are considered to be most meaningful. The requirements were then synthesised in five topics: enabling technology; indoor climate and working environment; energy and resource utilisation; safety, security and reliability; and adaptability. Together, these topics provide a comprehensive picture of the issues that must be considered in the development of a smart building.

The objective of the functional requirements lies in the definition of the word – to describe the requirement for desired functions without describing specific supplier-dependent solutions. The complexity of each functional requirement increases as one moves up through the ambition levels. In the fulfilment of the requirements at the upper levels, it is assumed that the values achieved at lower levels are not reversed. The functional requirements are developed such that achievement will largely be independent of outside circumstances such as building site, neighbourhood and geographic location.

Enabling technology

A smart building presumes the existence of certain enabling technologies which the other functions can build on. Key aspects are how different systems are able to communicate, sharing of structured data and the maturity of the digital twin.

ID	Functional requirements	0. Automated	1. Smart ready	2. Smart standard	3. Smart predictive	4. Smart cognitive
1.1	Use of open standards of communication between systems to enable data exchange.	Systems based on both open and proprietary protocols.	All systems communicate both ways through open, standardised TCP/IP protocols (e.g. BACnet).	The systems have open and documented APIs which simplify data exchange.	–	–
1.2	Integration of control systems[1].	Some control systems are integrated one-to-one based on gateways (protocol converter).	All relevant control systems can be integrated towards one central system.	Interacting control systems. Data are utilized across systems.	Control systems are predictive and share data about expected future conditions.	Control systems are self-learning, and improve their prediction models based on historical data.
1.3	Data availability, e.g. through use of sensors and multisensors.	A small number of sensors are used by several systems.	No unnecessary duplication of sensors. Real-time data are available for all relevant systems, including future systems.	Simplified and flexible sensor system achieved through extended use of multisensors and simple integration of extra sensors as required (e.g. when commissioning a building).	The sensor system is designed for high reliability through self-testing sensors, simple renewal of sensors and use of redundant sensors if necessary.	Machine learning algorithms verify system quality and reveal system errors.
1.4	Structural data collection and analysis.	Limited and unstructured data collection.	Collection of structured real-time data. The data structure used should be documented and available. No unnecessary duplication of data.	Structured collection and storage of historical data. Data can easily be made available to third parties.	Large amounts of data are used for prediction and user guidance.	Large amounts of data are used by self-learning systems to increase control precision in regular operation. Historical data are used for learning across several buildings.
1.5	Maturity level of digital twin.	Updated digital model provides an overview of the building's physical components (objects), structure and amounts.	The building's digital twin stores product information (e.g. environment and quality) and FDV (management, operation and maintenance) documentation related to the objects. The digital twin may be updated in case of changes, and is enabled for logging of operational data related to rooms and objects.	The digital twin is the central information carrier regarding building components, operational and user data.	The digital twin constitutes a superior digital copy of the physical building, and may, with or without use of related software, make its own simulations and predict building conditions in specific scenarios.	The digital twin improves its prediction models and gives recommendations as to how the building can adapt to future short-term and long-term needs.
1.6	Technical networks.	One separate network per technical system.	One common technical network for all technical systems. The network can be segmented and supports access control with a centralised access register.	All connected units are assigned access to the right segment, based on the unit's defined function and rights. Traffic and conditions in the network are monitored.	The network monitors data traffic and detects anomalous data streams. The system issues alerts and handles deviations.	The technical network is self-learning and self-protecting.
1.7	Network access for users.	Different Wi-Fis depending on tenants.	The building is enabled for common indoor Wi-Fi.	Common Wi-Fi for all tenants in the building.	Any cabled network serves all tenants in the building.	–
1.8	Mobile traffic over wireless network.	Building not adapted for mobile traffic over wireless network.	The building is enabled for mobile traffic over common Wi-Fi.	Building users have access to Wi-Fi voice and message services.	–	–
1.9	Positioning people and equipment in the building.	The building does not offer any positioning services.	The building is ready for indoor positioning based on Wi-Fi triangulation, Bluetooth beacons or a combination of these. Required wireless access points (WAP) and beacons are installed.	Users are assisted in navigating the building based on their position. Mobile equipment is traced and positions made available to users.	The building offers positioning services for users so they can locate colleagues and reveal their own location.	–

[1] Lighting, shading, HVAC and plumbing, BAS (building automation system), ABA (fire detection), AAK (access control), AIA (intruder alarm), TVO/ITV (video surveillance), AV (audio-visual), visitor registration system, conference room booking, lifts, etc.

Indoor climate and working environment

A key objective of smart buildings is to ensure better, more user-tailored and smarter control of the indoor climate and working environment. In other words, how temperature, ventilation, lighting, noise and ergonomics will facilitate good health and high productivity for all employees.

ID	Functional recuirements	0. Automated	1. Smart ready	2. Smart standard	3. Smart predictive	4. Smart cognitive
2.1	Thermal environment.	Temperature is controlled according to preset levels and hours of operation.	The building's system enables inclusion of other data sources (e.g. presence and conference room calendar) for temperature control. If the building features openable windows, these must be equipped with sensors for opening and outdoor air quality.	The building's system enables real-time data exchange with users, e.g. about temperature in different zones. Overall control of cooling and heating systems in relation to other systems, taking e.g. open windows into consideration.	Rule-based temperature control according to information on future events, e.g. conference room bookings and weather forecasts. The system receives and stores feedback from unique users and responds e.g. by adjusting temperature or providing personal user guidance.	The system is controlled based on a vast range of input data, including usage patterns, and uses historical data to improve its predictive models to ensure satisfied users.
2.2	Atmospheric environment.	Air flow rate is controlled according to preset CO_2 levels and hours of operation. No materials contain substances on the BREEAM-NOR A20 environmental poison list.	The air flow rate can be controlled based on several real-time data sources (e.g. activity and emissions from materials). Low emission materials have been used to enable reducing the air change rate. If there are openable windows, these must be equipped with sensors for opening and outdoor air sensors.	Users can influence the air flow rate naturally and / or mechanically. Overall control of cooling and heating systems in relation to other systems, taking e.g. open windows into consideration.	Rule-based air flow control according to information on future events, e.g. conference room bookings and weather forecasts. The system receives and stores feedback from unique users and responds to these, e.g. by adjusting temperature or providing personal user guidance.	The system is controlled based on a vast range of input data, including usage patterns, and uses historical data to improve its predictive models to ensure satisfied users.

ID	Functional requirements	0. Automated	1. Smart ready	2. Smart standard	3. Smart predictive	4. Smart cognitive
2.3	Daylight and lighting.	Lighting is switched on and off based on presence (movement sensors) and hours of operation. Use of low energy light sources only, such as LED and fluorescent tubes. Users can regulate the lighting level in their field of activity according to needs and work tasks.	Lighting control system based on presence, level of daylight and hours of operation. The building's design allows for optimal use of daylight. The lighting system is divided into suitable zones and equipped for two-way communication in the control system.	Quantity of light and colour temperature can be controlled by several factors such as time of day and season.	The lighting system receives feedback from unique users and provides users with information and guidance.	Quantity of light and colour temperature can be controlled based on individual physiology and preferences, according to the human centric lighting principle.
2.4	Acoustics, noise and vibrations.	Acoustic features are adapted to the function of the building. Noise and vibrations according to applicable regulations.	Acoustic features can be adapted to accommodate changes in use of the building. No vibrations or noise from technical installations in work zones. Monitoring of noise level.	Acoustic features can easily be adapted to accommodate changed use of the building (e.g. movable noise reduction elements). Noise levels are communicated to users in real time.	Active adaptation of acoustic conditions and noise reduction based on noise level, both in real time and expected noise level. The system communicates expected noise levels to users.	The system is self-learning and uses historical data for usage patterns, acoustic conditions and noise levels to improve its predictive models and active adaptation.
2.5	Ergonomic environment.	Universal design requirements are met. Work stations and devices are adjustable to user needs.	Work surroundings encourage versatile use. Work stations are equipped with sit stand desks.	Services that monitor activity levels and provide statistics on individual and group level are offered to the individual user and group.	Services that monitor ergonomic conditions at the work stations are available. The system provides advice to users to avoid overstrain and injuries.	The ergonomic system is connected to other user data (e.g. absence data) and uses machine learning to improve its predictive and advisory models.

Energy and resource utilisation

Sustainability and energy efficiency are often elements included in definitions of smart buildings, and this is also emphasised in this guide. The focus is on the building's energy and resource utilisation, independent of external factors such as the surroundings and geographic location.

ID	Functional requirements	0. Automated	1. Smart ready	2. Smart standard	3. Smart predictive	4. Smart cognitive
3.1	Energy performance of the building.	TEK17 (Regulations on technical requirements for construction works) / Energy class A.	The building satisfies the requirements of an nZEB according to the future-built definition.	The energy performance of the building is communicated to users in real time.	–	–
3.2	Consumption of electricity and unit control (lighting and equipment).	Lighting is controlled based on predefined hours of operation and sensors. Two-way communication for some equipment types only.	All lighting and relevant electrical equipment should be able to provide two-way communication.	Units are controlled with optimal energy consumption and effect based on several data sources (e.g. presence, solar shading and level of daylight) in real time. Energy consumption is measured and logged.	Units are controlled with optimal energy consumption and effect based on predicted needs (e.g. based on expected use and weather forecasts). Simulations of simultaneousness (e.g. by using the digital twin) prior to construction ensures reduced installed capacity and increased capacity utilisation.	Units are controlled with optimal energy consumption and effect through large amounts of operational data and machine learning. Learning generated by the building is shared with other parties involved in the project, and can be used in future projects.
3.3	Refrigeration and air conditioning systems and thermal energy supply.	The refrigeration and air conditioning systems satisfy TEK17.	The refrigeration and air conditioning systems have an overall design (combination of passive and active measures) and are easy to optimise in operation. All relevant units (e.g. heat pumps, valves, fans and temperature sensors) and zones in the building should be able to provide two-way communication.	The systems are controlled and operated with optimal energy consumption based on several data sources (e.g. actual weather conditions, usage patterns and building response) in real time. Energy and effect control enabled based on external information sources and grid integration.	The systems are controlled and operated for optimal energy consumption based on usage patterns, grid integration and weather forecasts. The system prepares for coming warm and cold spells based on set algorithms. Simulations of simultaneousness prior to construction allow for reduced dimensions.	The building is self-learning and improves control and operation algorithms according to usage patterns, grid integration, weather forecasts and the actual weather. Learning generated by the building is shared with parties involved in the project, and can be used in future projects.

ID	Functional requirements	0. Automated	1. Smart ready	2. Smart standard	3. Smart predictive	4. Smart cognitive
3.4	Building integration with grid, energy production and storage.	No grid integration. No production or storage of renewable energy.	System for production, storage and distribution of renewable energy has an integrated design, enabling optimised operation, including automatic cuts in unprioritized loads. All relevant units should be able to provide two-way communication.	Neighbourhood peak load will be reduced as the building's control systems communicate with each other (e.g. through load balancing and base load cuts).	A network of local neighbourhood parties exchange energy continously, electrical as well as thermal, based on some information sharing (e.g. energy prices and effect availability and tariffs). The building and its neighbourhood can communicate with external networks (e.g. in a smart city).	Total energy consumption and peak load in the neighbourhood are minimised through coordinated and widespread sharing of information and energy, in addition to exploitation of self-learning control systems.
3.5	Waste management and resource efficiency.	Waste sorting is available in relevant places in the building's work zones and cafeteria.	Sorted waste share, paper consumption and use of other relevant resources are measured and trends presented to users.	The building and its interior are designed to nudge users towards making resource efficient or health promoting choices, and the effects are presented to users. Information about the number of people present is used to calculate daily cafeteria demand.	Food waste is further reduced by tracking unique users' lunch preferences, which together with information about presence, is used to adapt daily quantities based on the people who are expected for lunch. The effect of reduced food waste is communicated to users.	Historical data and machine learning are used to improve accuracy in the calculations of cafeteria demand.

Safety, security and reliability

Smart buildings are expected to contribute to increased safety, security and reliability that goes beyond the current standard. This applies to personal safety and security, IT security and the reliability of the building and its systems.

ID	Functional requirements	0. Automated	1. Smart ready	2. Smart standard	3. Smart predictive	4. Smart cognitive
4.1	Information architecture.	No requirements for overall information architecture.	An information management concept describes how building and user integrity will be secured, how the ownership of data generated by the building and its users is regulated, and how privacy and cyber security requirements will be protected based on planned and future functions.	–	–	–
4.2	Cyber security.	Information security requirements are met for each data and control system.	Relevant cyber security requirements are met as part of the building's basic design.	Built-in technical counter measures handle identified weaknesses in chosen technologies (BACnet, IoT sensors etc.).	Modern cyber security tools and methods are used to predict and detect security-threatening events and to issue alerts or handle such events. Data security systems use information from other systems (e.g. perimeter protection and positioning) to detect anomalies.	The building is self-learning and improves its algorithms to predict, detect and handle security-threatening events.
4.3	Privacy protection.	GDPR and other relevant statutory requirements are met for each data and control system.	Privacy by design principles are used when the building's functions are established.	GDPR and other relevant statutory requirements are met collectively for all the building's systems in cases where there is data exchange between the systems, e.g. about users.	GDPR and other relevant statutory requirements are met for new data sets / new insights generated through the use of algorithms to predict future activities in the building and among its users.	–

ID	Functional requirements	0. Automated	1. Smart ready	2. Smart standard	3. Smart predictive	4. Smart cognitive
4.4	Proprietary independent systems.	Proprietary independent systems.	Integrated systems.	Use of biometric data simplifies access control and governance.	The monitoring system recognises different situations and responds to these.	The monitoring system shares historical data in a network of buildings and improves its situational understanding based on events in own and other buildings.
4.5	Reliability in energy supply and network connection (data).	One connection.	Enabled for parallel connections or alternative supply.	Redundant connections.	–	–
4.6	Condition-based operation and maintenance.	Preventive maintenance and inspection based on provisions in the facility management system.	Condition-based maintenance based on sensors integrated with the facility management system.	Condition-based operation and maintenance based on sensor and user data connected to the building's digital twin. Sensors monitor conditions in the different parts of the building's shell and core, and its equipment.	Condition-based predictive operation and maintenance based on weather forecasts, system data, usage patterns and feed-back from users. Relevant status reports are presented to users, e.g. for cleaning.	Algorithms for condition-based operation and maintenance are improved based on historical data and machine learning.
4.7	Natural hazard safety systems (fire, flooding, surface water, landslides etc.).	Natural hazard safety systems according to applicable laws and regulations, including fire alarm installations according to the NS 3960 fire protection standard. Specific requirements in the zoning plan are met.	Barriers to flooding and surface water are integrated into the building (e.g. lock systems, swales and green roofs). Relevant systems are enabled for automatic communication with emergency services.	Relevant systems communicate with emergency services, and provide information about events and status prior to arrival in case of call-outs. Sensor data from other systems are used for monitoring and detection.	Sensor data from other systems are used for monitoring and detection. In case of a call-out, emergency services have access to information about where people are located in the building.	Safety systems communicate and interact with neighbouring buildings and relevant infrastructure, e.g. about handling of surface water.

Adaptability

A high level of adaptability in relation to changing needs is desirable both in a sustainability perspective and a user perspective. This means that the building can have a high utilisation degree and yield maximum value throughout its entire lifecycle.

ID	Functional requirements	0. Automated	1. Smart ready	2. Smart standard	3. Smart predictive	4. Smart cognitive
5.1	Multifunctional spaces (optimal daily / yearly utilisation).	–	–	Multifunctional spaces across tenants, e.g. co-use of conference rooms.	Spaces with multifunctional use throughout the day and alternative use outside normal working hours. The building's design enables availability for external users (e.g. safety and fire), and availability data are shared by means of open protocols for use of other applications.	The building communicates with other buildings about needs and suggests measures for increased space utilisation.
5.2	Active space utilisation (optimal daily / yearly utilisation).	An updated digital model provides an overview of quantities (m²) and types (category) of space.	Enabled for interaction between buildings and user, where the digital model can be connected to user data and registered needs.	User interface where floor plan, actual use (sensor data) and users' registered space needs (booking of rooms/spaces) are seen in context. Data are stored for future learning. The system contributes to optimal day-to-day utilisation.	The system includes data on work practices, productivity and satisfaction for individuals, groups and professions, learns from other buildings, and generates recommendations for best possible long-term space utilisation.	Data for optimalisation of space use are entered in systems providing larger area perspectives (interaction between buildings) and / or a life-cycle perspective (change of purpose).
5.3	Decision basis for fit-out and other changes of building.	Updated digital model provides an overview of the building's physical components, structure and volumes.	Digital twin collects all available information relevant for physical fit-out, and makes it available for decision-makers.	Decision basis for fit-out of the building is collected from a digital twin, and can easily be shared with involved parties. Environmental and climate parameters are included in the decision basis.	The digital twin generates recommendations for fit-out and other changes based on operational, environmental and user data.	The digital twin recommends fit-out of the building and other changes based on data from the relevant building, in addition to neighbouring buildings and surroundings.

8 References

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List of photos and illustrations

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