A Danish case study

Use and Accessibility of Building- and Energy Data to Increase Flexibility Potentials in Public Buildings

Danish Energy Agency

COWI

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Published by:
Centre for Global Cooperation, Danish Energy Agency

Date of Publication: December 2024

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Background

This report is funded through the Energy Governance Partnership Programme (EGP), under the Centre for Global Cooperation in the Danish Energy Agency (DEA), aiming to share best practices to decarbonize the energy sector through a government-to-government cooperation, to accelerate the reduction of global CO_2 emissions.

The program includes international partnerships with the Netherlands, USA, United Kingdom, Germany, Japan, South Korea, Poland, Baltics and France.

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Foreword

For decades, Denmark has worked for an ambitious approach to energy efficiency, both in the EU and globally. As a country, the Danish energy efficiency efforts have resulted in the ability to keep consumption levels steady, despite a significant amount of growth over the past three decades, while benefitting the climate, the way of using energy, and the everyday lives of people.

However, recent years events with surging energy prices and uncertain security of supply, have accelerated the need to further develop the area and build upon the work of the past few decades.

Energy efficiency needs to become more focused on using energy in a smart way and with careful thought about its pivotal role in the future green energy system. Up until now, energy efficiency efforts have only to a limited extent focused on when on the day the energy is consumed. In the future it is important to focus on the time of use of energy to deliver flexibility to the energy system where energy consumption matches the expansion of renewable, fluctuating energy production and the growing electrification of society.

This requires a smarter and more efficient energy consumption that ensures the energy consumption matches the energy production, in order to reduce costs for consumers and enterprises, improve the security of supply, and contribute to a well-balanced energy system based on renewable energy sources.

This development requires a more digital, efficient, and integrated energy consumption. At the same time, the energy must be used flexibly during all stages, so that energy consumption can increasingly be managed based on the production of renewable energy. This requires that energy efficiency efforts are put into a framework based on a systemic understanding of how much, when, and which kind of energy is produced.

This report delves into the intersection of building data and flexibility potentials, highlighting how modern data-driven approaches can unlock new opportunities for managing energy use. The focus is on public buildings in Denmark, which are not only substantial consumers of energy but also serve as a leading example of sustainable practices.

Executive summary

Public buildings are managed by public institutions and can therefore play a role in the policy and overall strategy, to obtain energy flexibility and become a leading example. Denmark, as a member state of the European Union must, as well as other member states, implement the EU directives into national policy. Public buildings must lead by example, and all building users and owners are encouraged to implement energy efficiency improvements. But, what is the status of the public building stock in Denmark? Are they ready to leverage their use of energy and flexibility?

This case study delves into six case studies from 5 Danish municipalities—Aabenraa, Assens, Favrskov, Silkeborg, Odense, and 1 case from the Government, placed in Copenhagen (see Figure 1), spanning over different building types and usage. These cases show different uses and approaches for Energy management systems (EMS), Energy Performance Certificates (EPC), Building management systems (BMS), and Facility management (FM). The cases reveal both successes and challenges in the utilization of building- and energy data to achieving flexibility.

Findings indicate that while some buildings have integrated advanced energy management solutions, none of the interviewed municipalities currently control their buildings to generate energy flexibility actively. The absence of a structured market for distributed energy flexibility is a key challenge, although technological advancements in automated control systems, data integration, and real-time monitoring offer new opportunities.

Denmark's increasing reliance on renewable energy has made energy flexibility a pressing issue, as fluctuations in wind and solar power production can create imbalances in the grid. The report highlights that many Danish public buildings are equipped with smart meters, allowing for dynamic electricity pricing, but the potential for automated demand response and real-time energy optimization in public buildings remains largely untapped.

Future improvements will require:

- Upgraded digital infrastructure to enhance data accessibility and integration between EPCs, BMS, and EMS systems.
- Increased automation to enable public buildings to adjust energy consumption dynamically based on market signals or grid demand.
- Aggregation of small-scale energy flexibility contributions, allowing public buildings to participate in emerging flexibility markets.

By leveraging these advancements, public buildings can become active participants in a more resilient and efficient energy system, reducing operational costs while supporting Denmark's climate goals.

The report is supported by the Danish Energy Agency, under the Energy Governance Partnership. The case studies and content of the report are made in collaboration with consultants from COWI.

Figure 1. Map of Denmark with markings of the 6 case studies.

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Introduction to the public building sector in Denmark

The public building sector in Denmark consists of approx. 43 million m^2, distributed between state institutions (13.1 million m^2), municipalities (28 million m^2) and regions (4 million m^2). It includes various building types, user purposes, and consumption patterns. From castles, office buildings, hospitals, schools, kindergartens, libraries, and universities to radar stations, elderly homes, and toilet buildings.

To ensure the public building sector leads by example, all building users and owners are encouraged to implement energy efficiency improvements through various measures. Yet the distribution of responsibilities across the entire public sector adheres to the principle that tasks that can be managed locally are handled at the local level.

As such, strict requirements have been implemented in a circular for all state institutions, from 2021-2030, whereas energy-saving efforts in municipalities and regional buildings are based on voluntary commitments. It includes: reporting of energy consumption and energy efficiency plans in a national database, compliance with energy requirements in public procurements (e.g. products, services, rental agreements for buildings), etc.

Read more about the effort in state institutions at https://ens.dk

In addition to achieving two energy-saving targets by 2030:

1) Reduce energy consumption by at least 42.480 MWh compared to 2020 in buildings that are both owned and used by the central government, and
2) Reduce energy consumption by at least 10% in all additional buildings only used, but not owned, by the central government and underlying institutions.

Denmark as a member state of the EU must comply and implement the EU directives. The Energy Efficiency Directive (EED) and Energy Performance of Buildings Directive (EPBD) mandated several points related to energy efficiency of buildings and especially public buildings. The EED has been recasted in 2023, and is currently being implemented in Denmark. And the 2024 recast of EPBD is also being implemented.

Energy Performance of Buildings Directive (EPBD)

Minimum energy performance standards (MEPS): all non-residential buildings shall in 2030 be above the 16% worst performing buildings and by 2033 above 26%. Each member state is responsible for implementing MEPS through its own regulation, which may result in different approaches across countries. In the Danish context, Energy Performance Certificates (EPCs) will be used to assess the building stock and identify buildings that need to improve in order to meet the MEPS requirements.

One way to comply with the above energy requirements is - besides improving the thermal envelope and the use of energy-efficient energy service systems – to improve the control of the energy service system via investments in comprehensive BMSs and EMSs.

EPBD explicitly states that self-regulating devices must be installed when heat or cooling generators are replaced. The building must be equipped with measuring and control devices for monitoring and regulation of indoor air quality when it undergoes a major renovation. Buildings have to be equipped with building automation and control systems, as follows:

- by 31 Dec 2024, buildings with an effective rated output for HVAC (Heating, Ventilation, and Air Conditioning) systems of over 290 kW;
- by 31 Dec 2029, buildings with an effective rated output for HVAC systems of over 70 kW.

Energy efficiency directive (EED)

The 2024 recast mandates annual renovation of 3% of all public buildings at local, regional, and national level, which have a total useful floor area of more than 250 m^2. EU countries shall renovate the buildings to the nearly zero-energy building standard, whichcorresponds to EPC level B in a Danish context. Alternatively, renovations must obtain identical overall energy savings as the renovation of 3% of the buildings would have achieved, in other ways.

Use of Energy Performance Certificates on public buildings

It is mandatory to have an Energy Performance Certificate (EPC) on public buildings. This ensures transparency, accountability, and serves as a catalyst for energy-saving initiatives. The EPC requirements on public buildings shall comply with:

1. All new buildings larger than 60 m² must obtain an EPC before they are reported as completed or taken into use.
2. Public buildings exceeding 250 m² must undergo regular energy performance assessments and maintain a valid EPC. Each certification remains valid for up to 10 years, with mandatory renewal at its expiry.

The EPC obligation not only ensures compliance but also serves as a foundation for continuous improvement in the energy performance of public buildings.

The distribution of EPCs across public buildings in Denmark demonstrates significant variation based on ownership by the state**,** region**,** and municipal authorities**.** The below figure highlights the high amount of EPCs in labels C and D, but it also reveals that there is a portion of public buildings in labels F and G. These require retrofitting to align with the climate and energy goals, hence there is a need to find solutions to improve these buildings.

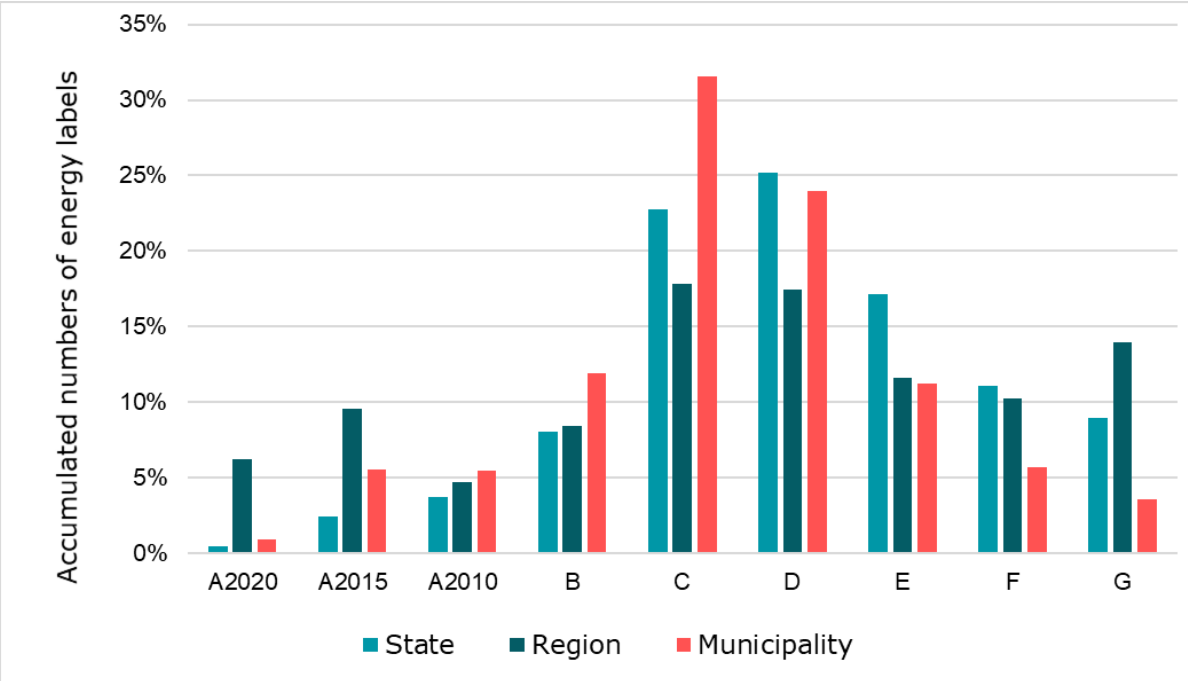


Figure 2. The distribution of Energy performance certificates of public buildings on ownership. EPC Label A is divided into 3 categories referring to the requirements in the building code for that year. ***Disclaimer: This figure only covers building with an EPC, as some public buildings does not have an EPC.***

Initiatives to ensure efficient public buildings

The public sector has strong ambitions to lead by example in the sustainable transition of the Danish building sector. From the establishment of public-private partnerships, development of strategic action and renovation plans to deliver on the Paris Agreement, and improving the built environment ensures the highest energy efficiency standards.

Public building initiatives include:

- DK2020-partnership
  - A partnership between Realdania[1], The National Association of Municipalities (KL), the regions, the think tank CONCITO, and C40 cities, aiming to support municipalities in their work on developing climate action plans, in compliance with the Paris Agreement and the National Climate Act.
- Energy- and Housing Analysis Database
  - A national IT tool for municipalities, administered by DEA, to analyze and target communication directly to relevant households and industry owners about energy-saving possibilities, such as subsidy schemes, renovation potentials, etc.
- EE-task force
  - KL in Denmark established a task force to support Danish municipalities with tailored guidelines and tools to ensure efficient building operations and maintenance.
- Energy leap
  - The municipality of Copenhagen has established a partnership between large building owners, administrators, and interest organizations, to lower the energy use in buildings.

[1] Realdania is a Danish association, supporting architecture, urban development and sustainable communities.

The Role of Intelligent Buildings in a Flexible and Balanced Future Energy System

Intelligent buildings can act as active participants creating a flexible, balanced, and sustainable energy system.

By leveraging advanced technologies, such as IoT, AI, and energy management systems, intelligent buildings can monitor, predict, and optimize energy usage in real-time. These capabilities may enable an active contribution to grid stability and efficiency.

Managing peak load times is crucial for balancing energy demand and supply. It includes shifting or reducing peak loads to help maintain system efficiency and stability and preventing strain on the energy infrastructure. Additionally, addressing internal needs, such as adjusting ventilation systems by dynamically modulating ventilation in different zones according to occupancy levels, makes it possible to reduce the load in underutilized areas while increasing it where demand is higher.

DEFINITION

Flexibility in buildings refers to the ability to dynamically adjust energy consumption patterns in response to external signals, such as energy prices, grid demand, or renewable energy availability.

Through the ability to swiftly adapt to changing conditions, requirements, and consumer patterns, using smart technologies, automated systems, and energy storage solutions, buildings can shift or reduce their energy use during peak periods and increase it when surplus renewable energy is available.

By understanding building consumption patterns, automatic adjustments can be made to operation systems and schedules to better match real-world usage, thereby improving overall efficiency. For example, smart heating, ventilation, and air conditioning (HVAC) systems can preheat or cool spaces during off-peak hours, while advanced battery systems can store energy for later use. This reduces peak load on the grid, minimizes congestion, and enhances the integration of intermittent renewable energy sources such as wind and solar.

Implementing flexible operational hours, such as variable start and end times, further allows buildings to align their usage more closely with actual demand. This not only improves efficiency but also reduces energy waste by ensuring that systems are only active when needed.

Read more about energy flexibility in annex 2.

KEY CONTRIBUTIONS

Data-Driven Optimisation

Continuous data analysis allows for predictive maintenance, energy waste reduction, and improved occupant comfort, all while optimizing energy efficiency.

Energy Storage and Distributed Generation

Equipped with energy storage systems and renewable energy technologies, intelligent buildings can store surplus energy and supply it back to the grid when needed. This decentralization supports grid resilience and reduces reliance on fossil fuels.

Demand Response and Load Shifting

Intelligent buildings can adjust energy consumption based on grid needs, shifting demand to periods of low energy use or high renewable energy availability. This reduces strain during peak times and enhances the integration of renewable energy sources efficiency.

Accelerating the flexibility potential in public buildings

Intelligent public buildings as a driver

A prerequisite to achieving a smart and intelligent building is the capability for real-time monitoring, data collection, and predictive algorithms.

It entails the deployment of sensors to enable continuous tracking of various parameters influencing the total energy consumption, such as occupancy, temperature, humidity, etc.

By gathering this stream of consumption data and processing it through analytics, it gives essential insight into energy usage patterns, enabling building managers to identify inefficiencies and unlock new opportunities to optimize building operations and maintenance through data.

> By automating adjustments, buildings can swiftly adapt to fluctuating occupancy levels and external environmental changes, enhancing their overall flexibility.

Automated control systems dynamically adjust heating, ventilation, air conditioning (HVAC), and lighting, based on real-time conditions. These systems can employ predictive algorithms to preemptively modulate energy usage, ensuring optimal comfort for occupants while minimizing waste.

Utilizing data exchange potentials

Analyzing and optimizing building usage patterns, including operating hours and occupancy trends, can identify opportunities for providing energy flexibility.

Integrating automation and real-time monitoring systems enables buildings to automatically adjust energy consumption based on current conditions. These technologies ensure optimal performance and resource utilization, minimizing the need for manual intervention and enhancing responsiveness.

Adopting standardized system requirements facilitates the integration and interoperability of various building technologies. Standardization ensures that different systems can work together seamlessly, thus enhancing the overall flexibility of building operations.
Efficient data exchange between different systems and stakeholders is critical for flexible building management. Enabling interactions between building management systems, energy providers, and external entities improves coordination in managing energy use and implementing flexibility measures.

Steps to ensure efficiently use of data

- Data verification processes must be in place to minimize errors. High error rates can lead to incorrect decisions and inefficiency.
- Implement robust maintenance and monitoring systems that can detect and eliminate sources of error, ensuring the integrity and usability of the data.
- Monitor and evaluate data continuously as the volume of data increases.

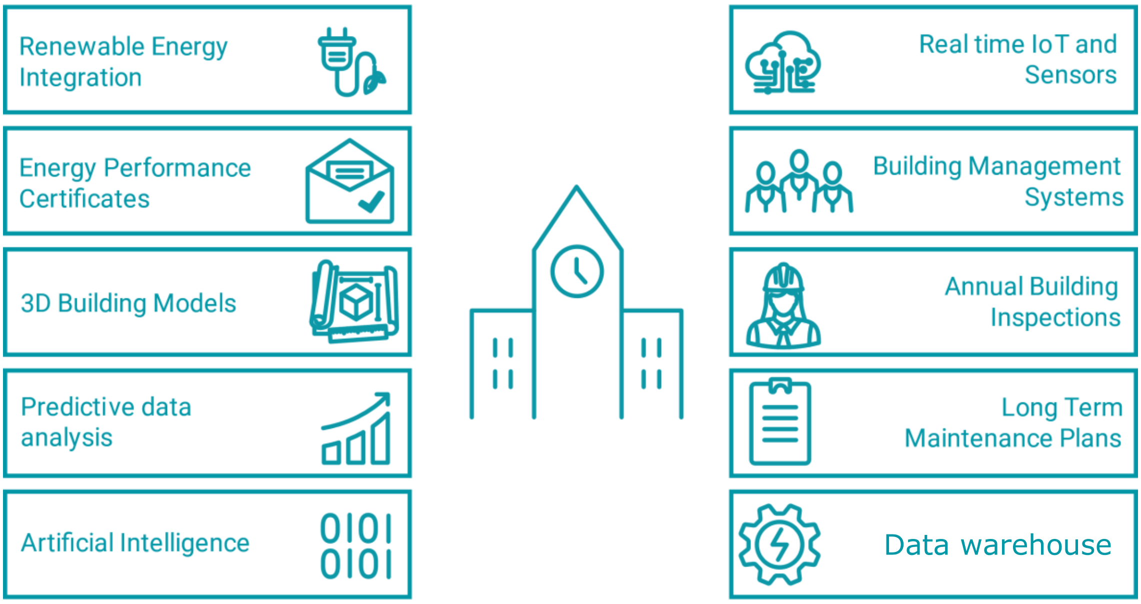


Figure 3. Graphical overview of factors enhancing the flexibility potential

Assessment of the Flexibility Potentials in Public Building Types

Public buildings, such as schools and daycare institutions, can achieve energy flexibility by incorporating modular construction, multi-purpose spaces, and smart technologies. Modular designs allow spaces to be reconfigured as needs change, while multi-purpose areas support diverse functions, from education to community events. Integration of intelligent systems, such as IoT-enabled energy and lighting controls, further enhances adaptability by optimizing building performance dynamically based on usage patterns.

Assessing the flexibility potentials includes:

- **Space Utilization Analysis**. Monitor how spaces are used to identify underutilized or overburdened areas.
- **Consumptions patterns.** Assess energy consumption patterns to identify opportunities for automation or sustainable upgrades.
- **Building User Feedback.** Collect input from occupants to align improvements with functional requirements.
- **Building Condition.** Evaluate the physical state and adaptability of structural elements, particularly in older buildings, to determine the feasibility of modifications.
- **Technology Integration Potential.** Examine existing infrastructure for compatibility with smart technologies to enhance operational efficiency.

Factors influencing flexibility

- Digital Infrastructure optimization, i.e. integrated IT systems
- Building user involvement to ensure efficient operations in consideration of daily, practical usage
- Automated technical solutions, allowing for dynamic changes in usage while maintaining optimal conditions
- Building operation organization, as variation leads to significant differences in the flexibility and efficiency of daily operations, as well as how data-driven the approach is

Public Schools

Building Type Characteristics

Public schools encompass a wide variety of structures, functions, and construction periods, making them challenging to define uniformly. Many buildings date back to the 1920s, with a significant number constructed post-1950s to accommodate the baby boom. Schools typically consist of multiple buildings, often with extensions added over the years, resulting in a mix of architectural styles, construction quality, and technical installations.

General information

There is approx. 1,400 public schools in Denmark, covering primary and lower secondary education (grades 0-9, with an optional 10th grade). In 2023, the total number of pupils was 678,544. *Source: www.dst.dk*

Beyond serving as spaces for education, schools function as workplaces for teachers and administrative staff. Many also host additional facilities, such as sports halls, libraries, swimming pools, dental care clinics, and youth clubs, making them integral to the community. Their multifunctional nature requires a high degree of adaptability to accommodate diverse activities and user needs.

Factors enhancing flexibility

Schools' technical systems reflect the broad range of their construction and renovation timelines, often blending older and modern technologies. Heating, ventilation, and lighting systems frequently combine centralized and decentralized systems and controls. Renovations in recent years have prioritized energy efficiency and indoor climate improvements, integrating systems like Building Management Systems and indoor climate monitors. These tools collect data on room temperature, CO_2 levels, and energy usage, enabling energy management systems to optimize performance and address faults.

By leveraging these advancements, schools gather extensive data from their technical systems, providing a foundation for improving operational flexibility. This helps them adapt to the complex demands of their multifunctional roles while enhancing energy efficiency and user comfort.

Building User Flexibility

Public schools serve a broad user base, primarily students but also teachers, administrative staff, and community members. This diversity necessitates operational flexibility to balance educational needs, workplace requirements, and extracurricular or community activities.

Facility management is typically handled through a mix of centralized and decentralized approaches. Centralized organizations often rely on data-driven insights to improve efficiency and adapt operations, while decentralized setups benefit from specialized technical expertise, such as electrical, plumbing, or construction skills. Both approaches contribute to maintaining flexibility, though centralized systems may better integrate cross-disciplinary tasks and address complex operational challenges.

Daycare Institutions

Building Type Characteristics

Daycare institutions are generally small, either purpose-built or converted from existing structures like villas or apartments. Older buildings, often heavy and durable, contrast with lighter constructions introduced since the 1980s, some initially intended as temporary but later made permanent. Modern purpose-built facilities since the 2000s emphasize functional design, but flexibility is typically limited due to their straightforward and consistent use.

Variations in construction quality and architectural style exist, but technical systems remain simple. Renovations tend to be comprehensive, often affecting entire buildings, ensuring uniform functionality but offering limited adaptability for other uses or purposes.

General information

There is approx. 4,300 daycare institutions in Denmark, for children aged 0-6. These include a mix of public and private facilities, such as nurseries for children up to 3 years, kindergartens for ages 3-6, and age-integrated institutions that cater to both groups. Home-based childminding services are also included in the childcare system.

Source: www.dst.dk

Factors enhancing flexibility

Flexibility in daycare institutions is largely influenced by their technical systems and the simplicity of their operational needs. Older facilities often rely on natural ventilation and manual lighting controls, which suit their focus on outdoor activities but limit adaptive management. In contrast, newer facilities incorporate advanced systems, such as balanced ventilation and daylight-controlled lighting with motion sensors, which enhance efficiency but still provide limited operational flexibility.

Recent renovations have increasingly focused on energy efficiency and indoor climate improvements. Advanced systems now log data such as room temperature and CO_2 levels, providing valuable insights for optimizing operations. In municipalities with energy management systems, automated monitoring can alert staff to faults or inefficiencies, improving response times. However, many facilities still rely on manual data collection, which limits the scope and immediacy of operational adjustments.

While upgrades have enhanced specific technical capabilities, the overall flexibility of daycare facilities typically remains constrained by their limited functional and technical complexity.

Building User Flexibility

Daycare institutions serve two primary user groups: children aged 0–6 years and employees. The user base is therefore limited, and the buildings are generally not used for other community-related purposes. As a result, the operational schedule is well-defined, making these buildings easy to manage with simple and autonomous controls.

The maintenance staff responsible for operating daycare institutions are often shared with other buildings, such as nearby schools, where they have primary responsibilities but can handle building tasks at the daycare as needed. Furthermore, they are part of the operational organization of other public property owners, either through decentralized or centralized structures. These organizations can take on more complex tasks and support local operations staff, as described for schools.

Nursing Homes

Building Type Characteristics

The flexibility potential of nursing homes can be enhanced through smarter and more intelligent building solutions and digital infrastructure. Many nursing homes, built from the 1980s onward, feature good construction quality and energy efficiency. It is reflected in their layouts, which are frequently single-story structures with outdoor areas enclosed between the buildings, limiting direct public access. Some nursing homes may have multiple floors or separate protected housing units.

General information

Denmark has approx. 930 nursing homes, including public and private facilities. Most nursing homes are publicly operated, providing residential and healthcare services.

Source: www.dst.dk

Newer facilities often incorporate energy-efficient systems like automated lighting, heating, and ventilation, tailored to the needs of residents. These smart-systems can adjust dynamically based on occupancy or individual preferences. In older nursing homes, utility consumption is often allocated using shared accounting systems, whereas newer facilities may include individual meters, either as sub-meters or direct billing meters. Facilities equipped with BMS, data such as temperature and set-points are often logged.

Factors enhancing flexibility

Implementing BMS allows facilities to optimize energy use, reducing costs and environmental impact while maintaining comfort. In addition to adjusting lighting and climate systems automatically to meet residents' needs, supporting varied activities like relaxation, therapy, and socialization.

For buildings with decentralized controls, data logging is less common. However, newer or renovated buildings often feature controls capable of logging data and transmitting it to online portals, allowing centralized facility managers to utilize the information.

Some nursing homes may also host community-related activities. In these buildings, the systems should be designed to operate autonomously, minimizing the need for operational staff to adjust settings for each activity. Facility management staff in nursing homes often oversee multiple properties, as the daily operational needs of individual nursing homes are typically not substantial. Since the buildings' structural, technical, and functional characteristics are relatively straightforward, local operational staff usually handle daily tasks. For complex issues, they rely on centralized or decentralized management expertise.

Building Users Flexibility

Nursing homes serve two main user groups that define the operational requirements of the buildings. Care-dependent residents often need to independently adjust heating and ventilation in their private units, typically preferring higher indoor temperatures than in standard residential settings. Employees work in both administrative zones and residential units, which serve as their workplaces, with associated demands for proper indoor climate and working conditions.

Daily operations are managed by local facility staff, who often oversee multiple properties. The relatively straightforward technical and functional characteristics of nursing homes make them manageable with minimal intervention. For more complex tasks, local staff rely on support from centralized or decentralized facility management organizations, ensuring both routine and specialized needs are met efficiently.

Administrative office buildings

Building Type Flexibility

Administrative office buildings are typically relatively modern, often constructed from the 1960s onward, with the majority built after the 1980s. These buildings often include a full basement housing technical systems, archive rooms, storage, and often air-raid shelters. The floor plans vary widely, including small cellular offices, smaller shared offices, open-plan offices, meeting rooms, council chambers, canteens, and more.

General information

There is approx. 4,500 publicly owned office buildings in Denmark. They typically used for administrative work. Many of them are administrated by the Danish Building Agency.

Source: www.dst.dk

Many buildings incorporate skylights or other natural lighting solutions to address deep floor plans, improving daylight penetration. However, these features can lead to issues like cold drafts from inefficient aluminum frames or glazing that does not meet modern energy standards.

Buildings are typically operational during regular working hours (7:00–16:00), though town halls often have zones used into the evening for meetings and council activities. As a result, the operational schedules and flexibility needs can vary significantly.

Factors enhancing flexibility

The technical systems in place are often a mix of medium- to low-complexity solutions. Ventilation systems may include natural ventilation, exhaust fans, and mechanically balanced ventilation, distributed across different zones or functions. Heating is typically provided by radiators, though some buildings feature convector heating or ventilation-based heating, which can be challenging for maintaining stable and comfortable indoor climates.

Some administrative buildings also have comfort cooling systems or dedicated cooling for IT server rooms and UPS systems. Lighting systems are usually integrated into suspended ceilings, either as panels or downlights. Control methods for lighting vary significantly, ranging from simple on/off switches to motion sensors with continuous daylight adjustment.

As such, BMS allows for centralized monitoring and control of energy use. Advanced analytics and AI caoptimize heating, cooling, and lighting based on occupancy and external weather conditions. In addition, smart building technologies can benefit from using IoT sensors and automation to track real-time energy use and adjust operations to minimize waste. For example, lighting systems may turn off automatically when a space is unoccupied.

Additionally, the use of these property buildings can range from standardized office functions to public meetings or private council sessions, leading to significant fluctuations in building loads and operational requirements. This variability often requires facility managers to have the ability to access and adjust building controls dynamically to maintain efficient and flexible operations. In larger buildings with diverse functions, facility management teams often rely on organizational support for handling more complex operational demands.

Potentials and barriers for increased flexibility

In practice, flexible building management utilizes integrated systems to enable real-time, data-driven decision-making, allowing indoor climate controls to be adjusted to current needs while anticipating future changes, such as weather fluctuations or shifts in building usage. As a result, energy consumption and operational costs are reduced.

For facility management, it means that building management can be planned, using informed, data-driven insights.

By leveraging data from energy performance certificates (EPC), building management system (BMS) logs, energy management systems, and updated facility management (FM) programs, future decisions about adjustments, replacements, and optimizations can be thoroughly evaluated.

Additionally, there is an increasing focus on cross-source data integration. For example, data from different sources can be collected in data warehouses, making it easier to access via AI-driven systems. These systems can highlight potentials and ensure better data validation cost-effectively.

Utilizing Cross-source data integration in Denmark

Denmark's approach to data sharing supports energy flexibility in public buildings through three key elements:

- **Public Available Register for EPCs**
  The EPCs provide transparent, standardized information on energy consumption, efficiency rating, and improvement potential, supporting facility management to prioritize energy-saving measures and enabling benchmarking for policy development.

- **The Building and Housing Register (BBR)**
  The BBR database offers detailed information about all buildings, such as floor area, usage, construction year, and technical systems. Combined with EPC data, it provides a comprehensive understanding of building characteristics and energy needs.

- **Remote metering and Data Access**
  Utility companies widely use remote metering for electricity consumption, allowing consumers to access real-time data through online platforms while enabling facility managers to implement demand-side strategies and monitor energy efficiency improvements effectively.

Challenges to Implementation

Organizational preparation

Firstly, the organization must be prepared on how the implementation process should be approached, which can differ significantly depending on whether the organization is decentralized or centralized.

In decentralized organizations, multiple stakeholders may complicate decision-making and make it harder to choose and implement systems effectively. Reaching consensus on solutions may require substantial initial effort. Centralized organizations may have an easier time coordinating decisions but embedding these ideas and decisions across the broader organization that must adapt, can be equally challenging. This demands extensive effort, training, and ongoing commitment.

Implementing technical solutions

Another significant challenge is the high cost of implementing technical solutions, along with the operational expenses of managing data-driven flexible systems and buildings.

Data collection across various system solutions also presents difficulties. Once collected, the data must be processed and validated to be meaningful for users or systems. For example, the quality of energy performance certificates is critical when data is collected manually. Errors in manual processing can undermine the credibility of not just one certificate but all the building owner's certificates, as the data becomes unreliable.

While leveraging data can provide invaluable insights, it also raises significant concerns about data protection and security. Safeguarding sensitive information, such as details about care home residents, administrative employees, or operational staff, is essential. Robust cybersecurity measures are required, which adds complexity and increases costs.

Balancing benefits and barriers

In summary, while the adoption of increased building flexibility offers compelling benefits in terms of improved user experience, operational savings, and enhanced sustainability, it faces several hurdles, including high initial investments, technological integration challenges, resistance to change, regulatory constraints, and data security concerns. While there is considerable potential for better integration and utilization of data across different systems, achieving seamless integration remains a challenge due to the diversity of systems in use. The prospect of integrating these under a unified program is anticipated to improve data utilization significantly in the future.

EPC

Potentials
- Existing data is accessible and extensive
- Increased focus on energy performance and savings potential
- Simplified calculation method – process energy is not included
- Can be used to demonstrate compliance with EU requirements (EED) and others
- Increased market value

Barriers
- False data
- Political compliance at national (DK) or EU level
- Static EPC by law, resulting in many outdated EPCs
- Does not consider indoor climate quality, water consumption, materials, LCA, etc.
- Enforcement can vary across jurisdictions and countries
- Decreased market value with poor ratings

Technical installations

Potentials
- Increased availability of modern systems with open standards for management, data retrieval, and transmission
- Short lifespan of technical systems makes upgrades or renovations easier

Barriers
- Investments required to upgrade technical systems
- Parts of systems cannot be renovated, e.g., CA ventilation ducts for VAV systems

BMS

Potentials
- Better documentation of correct operations through logs
- Centralized access to operations, alarms, and system errors

Barriers
- Complex for some operational staff
- Expensive to operate
- Some systems and standards are closed

EMS

Potentials
- Provides an overview of energy consumption for properties and portfolios
- Enables reporting for green accounting
- Issues alerts to minimize waste and damage
- Offers analysis tools for improved operations

Barriers
- Many data points require maintenance and validation
- Older systems are not user-friendly
- Primarily targets operational organizations, not on-site staff

FM systems

Potentials
- Data can be maintained directly by service providers
- Tasks and data can be assigned to the appropriate personnel

Barriers
- Systems do not cover all needs
- Data can be overwhelming

13. februar 2025

People management

Potentials
- Decentralized: Staff can have strong ownership of their properties
- Centralized: High levels of knowledge can improve efficiency in operations

Barriers
- Decentralized: Many stakeholders can lead to a lack of oversight
- Processes and knowledge may not be well-anchored in the broader organization

Case 1: Aabenraa Municipality

The examined building in Aabenraa Municipality functions as a school, operating primarily on weekdays from 7:00 to 17:00.

Aabenraa Municipality has a system of decentralized management with an on-site service technician attached to the school and a centrally located energy manager responsible. The operating hours of these technical systems generally align with the building's schedule, though deviations during special events are not recorded in the building management system

Data Accessibility and Usage Challenges

One challenge the building management team faces is the limited server capacity for comprehensive data storage, which currently allows for only 8 days of data retention. The facility management team is working to expand this to 18 months to enable more thorough analysis and historical monitoring. Despite the current restriction, data is logged every five minutes, providing a granular view of consumption and performance.

Energy Data Practices and Efficiency Potential

The facility management team reports having access to reliable and valid energy data, which they leverage to identify and address inefficiencies. For instance, EnergyKey is utilized to monitor large or atypical energy consumption patterns, triggering investigative and corrective actions as necessary. Monthly reports further assist in highlighting discrepancies that might otherwise remain unnoticed, underscoring the potential for continuous operational improvement.

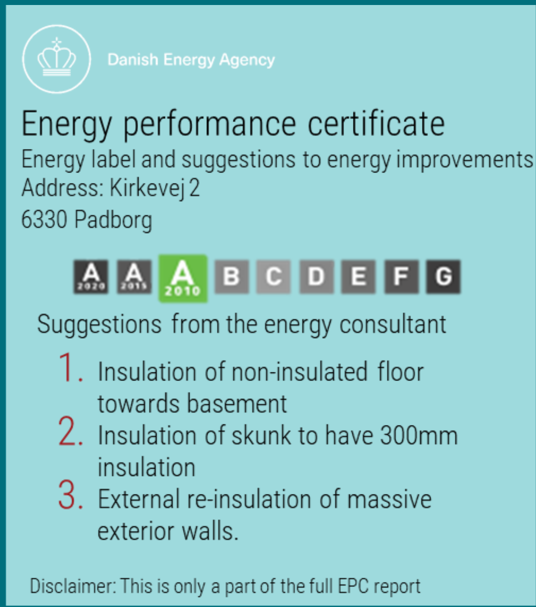
Energy Performance Certificate Utilization

The building is equipped with a valid EPC. Previous certificates were rendered obsolete by significant modifications to the building since issuing of the certificates. The development of new EPCs promises to provide more relevant data, which the municipality plans to incorporate actively into building operations.

The EPC also plays a crucial role in determining the viability of replacing adjacent components, making it a relevant tool for data-driven decision making. Replacements or renovations within the building are however typically deferred until components become defective.

Building Characteristics

EPC:


Danish Energy Agency

Energy performance certificate

Energy label and suggestions to energy improvements

Address: Kirkevej 2

6330 Padborg

Suggestions from the energy consultant

1. Insulation of non-insulated floor towards basement
2. Insulation of skunk to have 300mm insulation
3. External re-insulation of massive exterior walls.

Disclaimer: This is only a part of the full EPC report

- Valid EPC
- Data used for operational improvements and decision-making on replacements

EMS:

- EnergyKey
- Monitors consumption, generates monthly reports, and triggers alerts for anomalies
- Aiming for a 2% annual CO_2 reduction

BMS:

- Schneider Electric - EcoStruxure
- Comprehensive control over heating, ventilation, hot water, lighting, and more
- Provides visual alerts for maintenance staff

FM:

- NTI Mdoc FM, Timesafe, EnergyProjects
- Support thorough documentation, regular maintenance planning, and strategic oversight
- Bi-annual inspections and five-year maintenance plans

Energy Management System and Consumption Measurement

The examined building employs EnergyKey as its EMS, accessed both by local maintenance staff and the central administration with alerts for atypical consumption managed by NRGi Rådgivning. Training ensures that staff are well-equipped to utilize this technology.

Consumption measurement is another area of significant focus. Although most of the meters are automated, a handful still require manual readings. This includes comprehensive metering of key functions like heating, electricity, and water, with additional sub-metering for specific systems such as ventilation units and water posts. The presence of automated leak detection through sub-meters also highlights the building's commitment to proactive maintenance and efficiency.

Building Management System Integration

A fully integrated Schneider Electric EcoStruxure system manages the building's technical installations. The BMS sends visual alerts to maintenance staff whenever issues arise, ensuring timely intervention. Staff training and support agreements with Schneider bolster this system's effectiveness, though some manual intervention is still required for calendar adjustments and special events.

Facility Management System and Potential for Synergy

The facility's management is further enhanced by the use of NTI Mdoc FM, Timesafe, and EnergyProjects. These systems collectively support thorough documentation, regular maintenance planning, and strategic operational oversight. The bi-annual building inspections and five-year maintenance plans underscore a commitment to long-term efficiency and reliability.

Despite the varied and specialized systems in use, there is optimism about future integration. Currently, data from different systems is cross-referenced, albeit not fully systematized. The potential for more cohesive data utilization is significant, with aspirations for better synergy between EPC, EMS, BMS, and FM data. This would enable a more holistic approach to building management, optimizing both energy efficiency and operational performance.

Challenges and Opportunities for Improvement

Financial constraints remain a barrier to maximizing energy optimization opportunities. The decentralized management structure hampers the central organization's ability to act decisively on data insights. Therefore, a shift towards more centralized oversight could potentially unlock further efficiencies. Additionally, fostering a culture of data-driven decision-making within the maintenance staff could amplify these efforts.

The building management team has established a solid foundation for energy and operational management. Ongoing efforts to enhance server capacity, integrate new EPC data, and improve system integration are expected to further improve energy efficiency and operational performance in the future.

KEY BUILDING FACTS

Building information	
Construction year:	1909, 2015
Building use	Elementary school
Floor area (BBR)	12.363 m²
Energy consumption heating (metering)	467.452 kWh – 37,8 kWh/m²
Energy consumption electricity (metering)	242.336 kWh – 19,6 kWh/m²
Energy consumption heating (EPC)	593.180 kWh
Energy consumption electricity (EPC)	242.019 kWh
Energy consumption heating deviation (EPC/metering)	-27%*
Energy consumption electricity deviation (EPC/metering)	0%*
EPC status	A2010 (from 2024)
EPC proposal corrected	A2010
Link to EPC	**Ejendomsdata | boligejer.dk**
Link to BBR	**Kort - BBR**

**The deviation is between calculated energy consumption and measured data, negative is less than calculated.*

The measured energy consumption (metering) cannot directly be compared with the calculated energy consumption in an EPC. The measured energy consumption from meters does not only reflect the performance of the building. It is a mixture of the performance of the building, the behavior of the users, and the actual weather conditions. In opposition to this, the calculated EPC energy consumption is based on standard assumptions of user behavior and weather conditions. The measured energy consumption of a building can thus both be higher or lower than the energy consumption stated by the EPC.

Case 2: Assens Municipality

Building Overview

The examined building in Assens Municipality functions as a daycare center, hosting a kindergarten. The building is operational from Monday to Thursday between 6:30 and 17:00, and on Fridays from 6:30 to 15:00. Assens Municipality has transitioned to centralized building operation in 2020 which has opened new avenues for energy efficiency, which were less accessible earlier.

The Role of Energy Performance Certificate

One of the key tools used to guide energy efficiency efforts is the EPC. The EPC for the examined building in Assens is actively used for identifying and implementing energy-saving projects. Historical data from EPCs are integrated into the EnergyProjects platform, where it aids in comprehensive planning of replacements and renovations.

Energy Management System and Reporting Capabilities

The EMS used by the building is *Min Energi 2* which three years ago replaced the previous EMS *EviShine*, a system that is primarily used for monitoring production from photovoltaic panels. The EMS is pivotal in monitoring electricity and water consumption but does currently not monitor gas/heating consumption. It facilitates automated alerts and alarms for irregularities, helping the building management team respond promptly.

Future Implementation of Building Management System

Despite the operational benefits, the building lacks a centralized BMS, although plans are in place to implement the *Danfoss ECL* system with the shift to district heating. Presently, various standalone controls are utilized for heating, ventilation, lighting, and other systems. These controls are subject to regular adjustments to maintain optimal operation, yet a comprehensive, interconnected management system could streamline these efforts significantly.

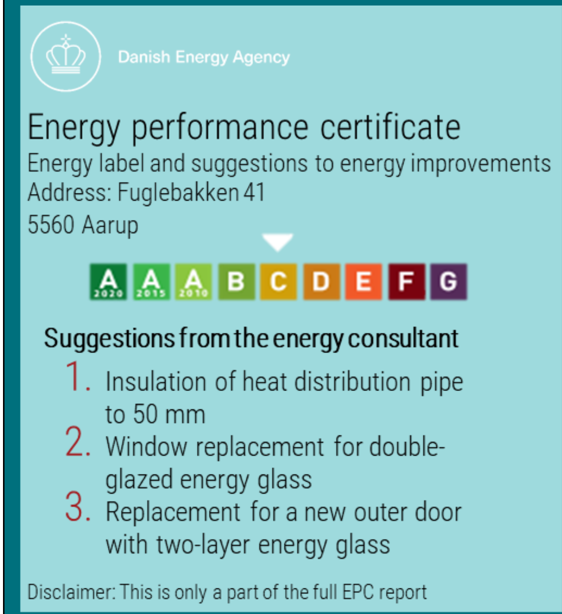
Generally smaller buildings in the municipality use *Danfoss ECL*, while larger buildings utilize BMS.

Facility Management System and Maintenance Activities

The FM system, *Dalux FM*, serves as a robust platform for operational efficiency. It hosts updated 3D models of the building, stores energy consumption data, and maintains service records. These capabilities ensure

Building Characteristics

EPC:


Danish Energy Agency

Energy performance certificate

Energy label and suggestions to energy improvements

Address: Fuglebakken 41

5560 Aarup

A2020 A2015 A2010 B C D E F G

Suggestions from the energy consultant

1. Insulation of heat distribution pipe to 50 mm
2. Window replacement for double-glazed energy glass
3. Replacement for a new outer door with two-layer energy glass

Disclaimer: This is only a part of the full EPC report

- Valid EPC
- Data used in EnergyProjects for operational improvements and collective implementations
- New energy labels in progress

EMS:

- Min Energi 2
- Monitoring of consumption, alarms for anomalies set for daily personnel response
- Central and local use for energy management

BMS:

- No comprehensive BMS; expected Danfoss ECL with future district heating integration
- A separate system for leak detection by Dantæt

FM:

- Dalux FM
- Complete 3D material documentation and energy usage recording
- Used for CO_2 reporting, manual service report uploads, and anticipated future direct service management
- Field inspections for critical maintenance and bi-annual inspections

that all installations and maintenance activities are documented systematically. Regular field inspections and reports reinforce this structured approach, ensuring any immediate maintenance needs are promptly addressed.

Integration for Enhanced Efficiency

The potential for enhanced efficiency lies in better integration of these diverse systems. The coordinated use of EPC data, EMS, BMS, and FM systems could substantially improve building operations and energy savings. For instance, aligning energy-saving suggestions from EPCs with real-time data from the EMS can reveal new opportunities for optimization. Similarly, combining EPC data with FM activities during maintenance planning can ensure comprehensive efficiency upgrades.

Overcoming Constraints and Unlocking Potential

The current constraints on time and resources are significant barriers. Personnel often lack sufficient time for in-depth analysis and optimal utilization of data. Addressing this challenge would require an investment in both financial and human resources. With adequate funding and staffing, the building management team can unlock its full potential for energy efficiency and operational excellence, further benefiting the examined daycare center in serving as a model for similar public buildings.

KEY BUILDING FACTS

Building information	
Construction year:	1981
Building use	Daycare
Floor area	496 m²
Energy consumption heating (metering)	40.282 kWh – 81,2 kWh/m²
Energy consumption electricity (metering)	6.275 kWh – 12,7 kWh/m²
Energy consumption heating (EPC)	55.670 kWh
Energy consumption electricity (EPC)	8.449 kWh
Energy consumption heating deviation (EPC/metering)	-38%*
Energy consumption electricity deviation (EPC/metering)	-35%*
Heating source	Natural gas
EPC status	C (from 2014)
EPC proposal corrected	B
Link to EPC	**Ejendomsdata | boligejer.dk**
Link to BBR	**Kort - BBR**

**The deviation is between calculated energy consumption and measured data, negative is less than calculated.*

Case 3: Favrskov Municipality

The examined building in Favrskov Municipality serves primarily as an administrative center. Its operations span weekdays from 07:00 to 17:00, with occasional utilization during evenings for meetings and occasional usage over weekends. This complex operational schedule necessitates efficient management and monitoring.

Facility Management and Staff

The centralized management team within the municipal administration is led by a department head. Under the department head, there are two main branches: one branch consists of service technicians who manage daily maintenance, and the other branch includes construction managers, project managers, and energy managers. This second branch is responsible for planning larger tasks and acts as a central entity for monitoring energy, technical operations, and maintenance. The centralized operational structure ensures a coherent approach to handling technical and operational aspects, which is crucial for maintaining efficiency.

Data and System Integration

Data reliability and accessibility are fundamental to the building's energy management practices. Despite occasional issues with systems like FA47 (remote meter reading) and Omega MS, data is generally reliable. The building plans are around 80% up-to-date and are available in a 3D format within the Dalux platform.

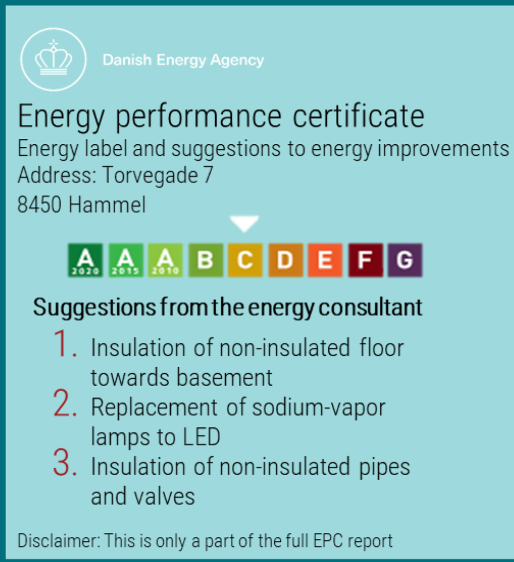
The building has a valid EPC, and recommendations are occasionally used during renovations. All EPC data is integrated into Power BI for cross-comparison. There are plans to transition from Power BI to EnergyProjects. EPCs are available to maintenance staff but are not commonly utilized, and the accuracy of the EPC data has not been verified. Since 1979, the building has undergone minor renovations, including lighting replacements and partial updates to the ventilation system.

Energy Management System

The EG Omega EMS is central to the building's energy strategy. Employed both locally by the facility management team and centrally by the administration, the EMS provides essential automatic notifications about unusual consumption patterns. This proactive monitoring allows for early intervention. Energy

Building Characteristics

EPC:


Danish Energy Agency

Energy performance certificate

Energy label and suggestions to energy improvements

Address: Torvegade 7

8450 Hammel

A2020 A2015 A2010 B C D E F G

Suggestions from the energy consultant

1. Insulation of non-insulated floor towards basement
2. Replacement of sodium-vapor lamps to LED
3. Insulation of non-insulated pipes and valves

Disclaimer: This is only a part of the full EPC report

- Valid EPC
- Data used in Power BI and EnergyProjects improvements and collective implementations
- EPCs captured in Power BI

EMS:

- EG Omega
- Monitoring consumption, anomaly detection, and generating reports
- Used both locally and centrally for comparative analysis and weekly/monthly reviews
- CO_2 reduction goal: to halve CO_2 emissions by 2025 compared to 2009

BMS:

- Schneider CTS (BMS)
- Controls central heating and selective ventilation units
- Provides visual alerts for faults

  Reviews of set points and adjustments by central energy responsible

FM:

- Dalux FM
- Comprehensive management of service reports, task assignments to vendors, and documentation
- Annual review day for local maintenance and operations

consumption is monitored using dedicated meters for heat, electricity, and water. Although some older systems still require manual readings, most are automated, indicating a partial need for modernization.

The building has successfully achieved its goal of reducing CO_2 emissions by 50% by 2025, largely due to a transition to CO_2-neutral district heating systems.

Challenges and Prospects

The building management team faces challenges such as limited staffing and resources, which hinder the full utilization of available data and systems. Additionally, exploring advanced technologies like artificial intelligence presents a promising avenue, though currently limited by cyber security concerns and IT departmental capacity.

In summary, while the examined building in Favrskov Municipality demonstrates a structured approach to energy management and data utilization, there is significant potential for further integration and modernization. By addressing current limitations and leveraging advanced technologies, the building can optimize its operations and enhance its energy efficiency more comprehensively. To enhance operations, more resources are necessary to balance data points and system relevance, avoiding both resource wastage and under-utilization.

KEY BUILDING FACTS

Building information	
Construction year:	1979
Building use	Office space
Floor area	3.644 m²
Energy consumption heating (metering)	323.480 kWh – 88,8 kWh/m²
Energy consumption electricity (metering)	110.694 kWh – 30,4 kWh/m²
Energy consumption heating (EPC)	460.000 kWh
Energy consumption electricity (EPC)	97.869 kWh
Energy consumption heating deviation (EPC/metering)	-42%*
Energy consumption electricity deviation (EPC/metering)	12%*
Heating source	District heating
EPC status	C (from 2017)
EPC proposal corrected	A2010
Link to EPC	**Ejendomsdata I boligejer.dk**
Link to BBR	**Kort - BBR**

**The deviation is between calculated energy consumption and measured data, negative is less than calculated.*

Case 4: Silkeborg Municipality

Property Data

The examined building in Silkeborg Municipality serves as a school and after-school care (SFO) center, utilized daily from 06:30 to 17:00, with very limited activities beyond these hours. This operational schedule emphasizes the need for efficient energy and facility management to maximize performance during active hours and minimize energy wastage outside these periods.

Facility Management and Staff

The facility management team consists of two technical service staff, supported by a larger property management center. An energy manager and three engineers with expertise in electrical, HVAC, and ventilation systems are key members of this central team. The centralized structure, which has been in place for 12 years, enables more autonomy in decision-making and standardization of processes across a portfolio of buildings.

Key Roles and Responsibilities:

- The central management team advises on BMS systems and oversees the daily operations of buildings managed by the facility management team.
- Methodological efforts are directed toward reducing energy consumption in areas that offer the highest value.
- The central management team is involved in new constructions, standardizing system paradigms, and participating in commissioning to ensure sustainability, energy efficiency, and quality.
- Autonomy in building operations is pursued due to challenges in resources on a daily basis. Buildings are designed to switch to standby modes when not in use and fully activate systems through PIR sensors when occupied (ventilation, heating, lighting).

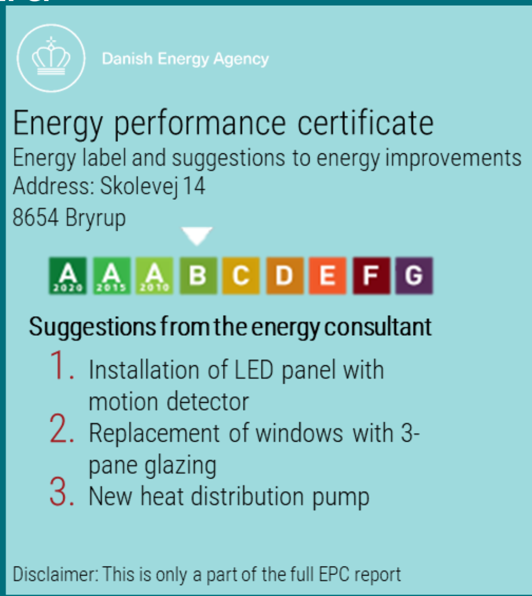
Data and System Integration

Data availability and reliability are considered robust, with the property management center ensuring relevant consumption and building data are accessible.

Danish Energy Agency

Building Characteristics

EPC:



- Valid EPC
- EPC data not frequently used due to preference for internally collected data

EMS:

- EnergyKey and ENTO
- Monitors consumption, generates reports, and triggers alerts for anomalies
- Automatic alerts via email, visual cues, and central notification managed by energy staff
- Goal: CO_2 neutrality by 2025

BMS:

- Schneider Electric StruxureWare and Danfoss ECL310
- Automatic alerts for operational deviations managed by central management staff

FM:

- Dalux FM and TimeSafe
- Central 3D models and data storage for facilities management
- Short-term maintenance plans handled by local staff; long-term plans managed centrally.

The building holds a valid EPC, but the data from these certificates is underutilized for maintenance due to doubts about its quality. Instead, the property management center prefers internally gathered data from extended service on technical installations and energy screenings which are registered in a centralized CAFM-system (Computer Aided Facilities Management). EPC data is accessed via PDF and Excel.

Energy Management Systems

The building uses two energy management systems: EnergyKey and ENTO Labs. EnergyKey is fully implemented and verified, while ENTO Labs is used for analyzing excessive consumption and deviations. Reports from these systems are sent to operational staff, and automated notifications about inappropriate consumption are delivered via email and visual alerts. EnergyKey is used by both local staff and central administration, with training provided to ensure effective usage. The municipality has set a goal to be CO_2 neutral by 2025, with EnergyKey assisting in tracking deviations from calculated energy usage.

The property is equipped with manual readable meters for heat, and water, which are read monthly. Electricity data is collected on an hourly basis via the electricity DataHub. The heat is supplied by natural gas, and there is a single meter for solar panel production. There is no automated water leak detection system, which management believes would help address leaks and irregular consumption patterns more effectively.

Facility Management

Facility management is conducted using the Dalux FM platform, supplemented by TimeSafe for managing building data and maintenance plans. The property management center envisions a future where Dalux handles all building-related data comprehensively.

Building Management Systems

The building employs Schneider Electric StruxureWare and Danfoss ECL310 for controlling key technical installations. The systems manage key technical installations and environmental controls like heating, ventilation, and water heating. Decentralized ventilation systems such as Airmaster units operate with internal controls.

Regular training and updates ensure that the facility management team can effectively manage these systems. Automatic alerts for technical faults and energy wastage are monitored centrally by energy staff, who then coordinate with the local operational staff for any required follow-ups.

Operational and Optimization Practices

Silkeborg Municipality undertakes several measures to optimize operations:

- Centralized Property Management and Monitoring: Enhanced decision-making and efficiency through a dedicated centralized team.
- Standardization and Involvement in New Constructions: Standardized paradigms for systems, ensuring quality and efficiency from the start.
- Role Clarification: Clear differentiation between central operational responsibilities and location-specific responsibilities.

Challenges and Prospects

- Autonomous Buildings: Silkeborg Municipality recognizes the difficulty in finding competent operational staff and is actively pursuing autonomous building systems. This includes leveraging AI for better system monitoring and integrating PIR sensors to activate systems only when buildings are occupied.

- Collaborative Software Solutions: Silkeborg's collaboration with Danfoss for tailored software solutions has ensured that new automation systems are well-received by operational staff, enhancing efficiency and user satisfaction.
- Comprehensive Involvement: The central management's role extends beyond day-to-day management to involvement in new constructions and procurement processes, ensuring sustainability and energy efficiency from the outset.
- Use of AI for System Monitoring: The integration of AI, particularly with Ento Labs for consumption monitoring, represents a forward-thinking approach, minimizing manual checks and maximizing data-driven insights.

Conclusion

In summary, the examined building in Silkeborg Municipality exemplifies best practices in energy management and data utilization. By centralizing operations, integrating advanced systems, and maintaining a dedicated team of specialists, Silkeborg stands out for its innovative and proactive management practices. Continued investment in AI and automation promises even greater efficiencies and enhanced energy performance, underscoring Silkeborg Municipality's role in sustainable building operations.

KEY BUILDING FACTS

Building information	
Construction year:	1960
Building use	Elementary school
Floor area	4.960 m²
Energy consumption heating (metering)	398.000 kWh – 80,2 kWh/m²
Energy consumption electricity (metering)	92.000 kWh – 18,5 kWh/m²
Energy consumption heating (EPC)	531.820 kWh
Energy consumption electricity (EPC)	229.623 kWh
Energy consumption heating deviation (EPC/metering)	-34%*
Energy consumption electricity deviation (EPC/metering)	-150%*
Heating source	Natural gas
EPC status	B (from 2020)
EPC proposal corrected	B
Link to EPC	**Ejendomsdata | boligejer.dk**
Link to BBR	**Kort - BBR**

**The deviation is between calculated energy consumption and measured data, negative is less than calculated.*

Case 5: Odense Municipality

Property Data

The examined building in Odense Municipality serves as a nursing home, operating year-round. The facility type demands uninterrupted operation and careful management due to the services it provides to its residents.

Current Operations

The building operates around the clock, with distinct schedules for its administrative and residential areas. The ventilation system for administrative areas runs from 7:00 to 16:00 on weekdays, while the residential areas have extended operation from 6:00 to 22:00 throughout the week. This segmentation ensures that the environmental controls align closely with the actual use patterns of different zones within the facility.

Data Practices and Challenges

Data accessibility and management are pivotal for efficient building operations. While the building does not generally face significant challenges in obtaining consumption data, water consumption data presents some difficulties due to outdated and incomplete technical documentation. This issue outlines the need for updated and accessible records to facilitate timely maintenance and operational efficiency.

Energy Efficiency Initiatives

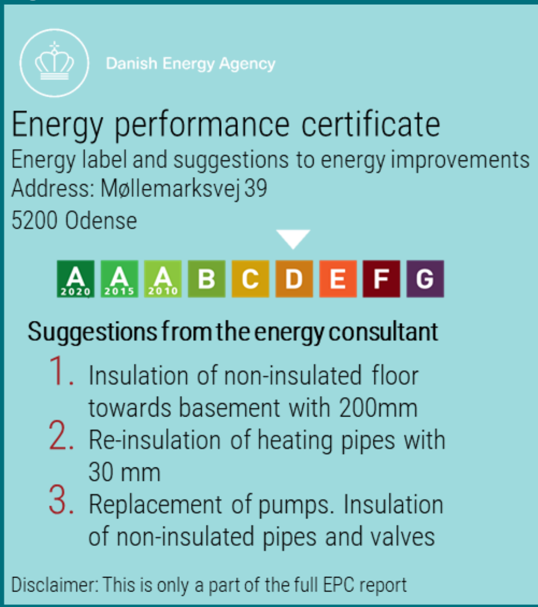
The central building management team in the municipality has implemented a measure called the "Nighthawk" initiative, which focuses on identifying standby electricity consumption in public buildings through EMS and then doing site inspections at night outside of normal operating hours to look and listen for unintended consumption.

Energy Management System

The building utilizes the EnergyKey system for managing energy consumption, though its usability and administrative burden are points of contention. Consequently, there is consideration for adopting an alternative system that is considered more user-friendly. This transition could potentially empower facility staff by allowing more efficient monitoring and management of energy consumption through customizable alerts and easier data access.

Building Characteristics

EPC:


Danish Energy Agency

Energy performance certificate

Energy label and suggestions to energy improvements

Address: Møllemarksvej 39

5200 Odense

Suggestions from the energy consultant

1. Insulation of non-insulated floor towards basement with 200mm
2. Re-insulation of heating pipes with 30 mm
3. Replacement of pumps. Insulation of non-insulated pipes and valves

Disclaimer: This is only a part of the full EPC report

- Outdated EPC from 2009
- Recommendations mostly implemented - future plans to enrich EPC data with additional registrations
- Accessible in EnergyProjects and Dalux

EMS:

- System: EnergyKey
- Locally and centrally used - monitoring consumption and generating alerts
- Plan to switch to a more user-friendly system

BMS:

- System: TREND alongside Danfoss ECL
- Controls heating, ventilation, and hot water systems with seasonal adjustments
- Centrally and locally managed

FM:

- Systems: Caretaker and Dalux FM
- Regular building inspections

Consumption Monitoring

The building is equipped with separate consumption meters for heat, electricity, and water, allowing for precise measurement of resource usage. However, many of these meters require manual readings by the maintenance staff as the meters are only remotely read by the utility companies. Manual readings are labor-intensive and introduces a risk of data errors. The existing water leak detection system is only partially automatic and lacks shut-off valves, suggesting further investment in modernizing these systems could benefit efficiency and data accessibility.

Control Systems

A TREND CTS (BMS), combined with Danfoss ECL, manages the building's heating, ventilation, and hot water systems. Administration of the BMS is shared between central and local teams, ensuring comprehensive oversight and effective on-the-ground operations. Facility staff receive ongoing training facilitated by service agreements with the BMS provider, ensuring they are equipped with the necessary skills to manage the system effectively. This training is periodically funded by the central management department to maintain consistent upskilling.

The BMS provides visual alerts within the software interface to notify staff of any faults or issues, facilitating rapid response and resolution. Although handling alarms at the central level can be overwhelming due to the volume, the alarm load is manageable at the examined location. This suggests that optimization of alarm management processes could further improve the efficiency.

Facility Management

The building uses Caretaker and Dalux FM for managing facility data and maintenance plans, however, the municipality reports that only Caretaker is designed to support nursing homes.

Data from BBR (Building and Property Register) is integrated with Dalux for more efficient data management, but the integrated data has not been verified. Reports and maintenance plans are generated annually, though deviations occur due to operational pressures.

Potential for Improvement

The building's management faces challenges such as limited resources and high operational workloads, which limit the scope for energy optimization and data application. Addressing these issues by upgrading outdated systems, enhancing data integration, and allocating additional resources for centralized management could significantly enhance the municipality’s operational efficiency and sustainability.

In summary, the examined building in Odense Municipality, as a nursing home with continuous operational demands, exhibits both strengths and areas for improvement in its current operational and data practices. By addressing data accessibility challenges, modernizing energy management systems, and integrating comprehensive data into a unified platform, the facility can maximize its potential for energy efficiency and improved operational performance.

KEY BUILDING FACTS

Building information	
Construction year:	1972
Building use	Nursing home
Floor area	5.220 m²
Energy consumption heating (metering)	478.716 kWh – 91,7 kWh/m²
Energy consumption electricity (metering)	184.680 kWh – 35,4 kWh/m²
Energy consumption heating (EPC)	526.420 kWh
Energy consumption electricity (EPC)	99.338 kWh
Energy consumption heating deviation (EPC/metering)	-10%*
Energy consumption electricity deviation (EPC/metering)	46%*
Heating source	District heating
EPC status	D (from 2009)
EPC proposal corrected	D
Link to EPC	**Ejendomsdata | boligejer.dk**
Link to BBR	**Kort - BBR**

**The deviation is between calculated energy consumption and measured data, negative is less than calculated.*

Case 6: The State

Property Data

The Royal Danish Library, focusing on the Holm building, serves as a book depository, reading room, and museum. It operates from Monday to Friday between 08:00 and 20:00, and on Saturdays from 09:00 to 18:00, remaining closed on Sundays.

A dedicated team of 13 personnel, comprising operational staff and project managers, is responsible for daily operations and maintenance across multiple locations. The technical systems are carefully scheduled to match the building's usage hours, ensuring efficient operation and resource management.

Energy Efficiency and Management

Rather than employing a conventional EMS, the building relies on a proprietary Excel system. This unique approach, while functional, emphasizes the need for integrating more sophisticated data management tools. The institution is committed to improving energy efficiency and CO_2 reduction across its state buildings, highlighting a forward-thinking approach to environmental sustainability.

Building Potential and Data Practices

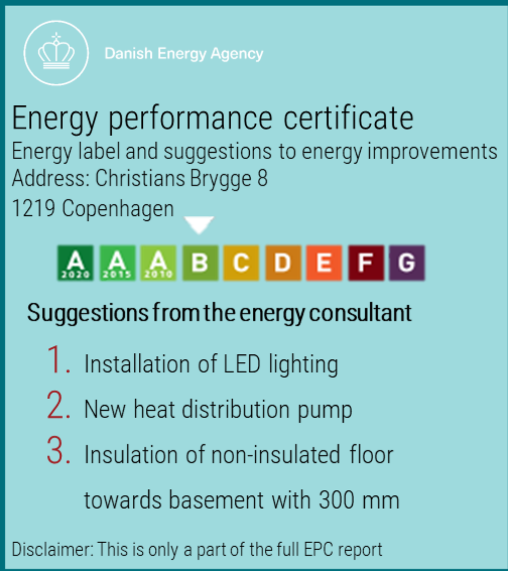
The facility is well-equipped with numerous sub-meters for monitoring heating, ventilation, and cooling systems, with some requiring manual monthly readings. Building documentation and schematics are also readily available, which significantly aids in technical renovations.

The data is generally reliable and recognizable. However, there is considered to be an untapped potential in further optimizing building operations and energy consumption. Current practices also include collaboration with energy consultants from SLKS to analyze atypical energy patterns, identifying areas for improvement.

Building Characteristics

EPC:

Building 8


Danish Energy Agency

Energy performance certificate

Energy label and suggestions to energy improvements

Address: Christians Brygge 8

1219 Copenhagen

A2020 A2015 A2010 B C D E F G

Suggestions from the energy consultant

1. Installation of LED lighting
2. New heat distribution pump
3. Insulation of non-insulated floor towards basement with 300 mm

Disclaimer: This is only a part of the full EPC report

- Valid EPC
- Proposals utilized for renovations and replacements

EMS:

- No dedicated EMS system is utilized

BMS:

- Systems: Trend CTS and Siemens Desigo CC
- Alarms provided via BMS, though the volume of alarms can be overwhelming

FM:

- System: Dalux FM
- Regular, though not always annual, building inspections for maintenance planning

Control Systems

The building is managed using two BMS systems: Trend BMS and Siemens Desigo CC. These systems are operated by experienced on-site staff who receive ongoing training to ensure they are proficient in using the systems effectively. The BMS systems help manage various building functions, including heating, ventilation, and lighting. The systems provide automatic notifications for faults or alarms, which can be delivered via visual alerts in the BMS program, emails, or SMS, ensuring that issues are promptly addressed.

Challenges and Recommendations

The primary barriers to more integrated data use include limited time and resources. Enhancing staff capacity and incorporating new data sources would improve operational and energy efficiencies. The focus on daily operations limits time for long-term optimization strategies. Additional resources and a structured approach to integrating data management systems could improve outcomes.

In summary, The Royal Danish Library employs a structured approach to data-informed building operations and energy management. While there are opportunities for improvement, the building has a solid foundation for continuous advancements in efficiency and sustainability.

KEY BUILDING FACTS

Building information	
Construction year:	1906
Building use	Museum
Floor area	19.029 m²
Energy consumption heating (metering)	799.000 kWh – 42,0 kWh/m²
Energy consumption electricity (metering)	181.000 kWh – 9,5 kWh/m²
Energy consumption heating (EPC)	1.390.050 kWh
Energy consumption electricity (EPC)	677.149 kWh
Energy consumption heating deviation (EPC/metering)	-74%*
Energy consumption electricity deviation (EPC/metering)	-274%*
Heating source	District heating
EPC status	C (from 2022)
EPC proposal corrected	A2010
Link to EPC	**Ejendomsdata | boligejer.dk**
Link to BBR	**Kort - BBR**

**The deviation is between calculated energy consumption and measured data, negative is less than calculated.*

Current Danish solutions
- nationally and globally

For decades, Denmark has pursued to be a frontrunner when it comes to energy efficiency with Danish enterprises playing a leading role globally in this area and the transition to renewable energy.

Based on Danish experiences, it has proven successful in pushing for an ambitious approach to energy efficiency, benefitting both the climate, our way of using energy, and the everyday lives of people, while also creating large markets for Danish enterprises.

Below is an overview of the available technical solutions, presented in the case study to ensure energy efficiency, while contributing to more intelligent buildings supporting a more flexible energy system.

Databased building solutions
Energy Performance Certificate (EPC) Database and Monitoring
Energy Systems Energy10*
EnergySystems EnergyProjects*
Microsoft Power BI*
BE18
Rockwool Energydesign
EK-PRO (discontinued)
Energy Monitoring System (EMS)
EnergyKey KMD*
EG Omega*
ENTO*
MinEnergi*
LEGACY (not energy management, but data collection)
OIS (not energy management, but data collection)
Building Management System (BMS)
Siemens CTS - Desigo CC*
Danfoss ECL*
Danfoss Portal/LeanHeat Monitor (ECL data collection)*
Schneider Electric CTS – EcoStructure*
Honeywell CTS - Including Trend, Centraline, Honeywell*
Priva CTS
Regin
Bosch
BuildingConnect
Facility Management (FM)
DALUX FM*
TimeSafe*
NTI FM*
Caretaker*
EnergySystems DV-plan
Plando
Main Manager
EG Bolig

Figure 4. Databased building solutions. *Encountered in the case study.

Energy Flexibility from Public Buildings

Increasing global energy demand, reduction of fossil fuels, and increasing evidence of global warming have generated interest in renewable energy sources (RES). However, energy sources such as wind and solar power have an intrinsic variability that can seriously affect the stability of the energy networks. Therefore, future high penetration of variable renewable energy sources forces a transition from "generation on demand" to "consumption on demand" to match the instantaneous energy generation. Buildings are expected to play a central role, where consumers and "prosumers" (e.g. buildings with PV) become energy flexible to satisfy the generation and/or storage needs of the energy networks (electricity and district heating grids).

The aim of the present report was, based on interviews with several municipalities, to investigate if and how public buildings may contribute to delivering energy flexibility to stabilize the surrounding energy grids.

None of the interviewed municipalities control their buildings to generate energy flexibility. This is no surprise as a market for handling small flexibility contributions from DERs (Distributed Energy Resources, which include buildings) is not yet in place (except for fleet operators managing charging stations for EVs). Denmark has started to phase out the large thermal power plants, which traditionally provided spinning reserves (energy flexibility) to the grid, and although renewable energy sources covered 63% of the annual Danish electricity demand in 2023, large interconnectors to neighbor countries have been sufficient to supply the necessary energy flexibility for stabilizing the power grid.

However, curtailment of the production from wind turbines and periods with negative electricity prices occur more and more often, although electrification of Danish energy has started in the form of the transition to individual heat pumps, large heat pumps in the district heating grids, VEs, electrification of industrial processes, etc. Energy flexibility and the requirements for making this available in public buildings are discussed in more details in Annex 2.

All buildings in Denmark have a smart electric billing meter. This means that all building owners have the possibility of having a payment scheme with dynamic pricing – i.e. paying the actual electricity price hour by hour. The actual production price varies quite much over the day. From January 2023, the end user price for electricity started to vary even more as the DSOs (Distribution System Operators) were allowed to apply more real cost transport tariffs. The cost of transporting electricity in the grid increases with increasing amount of transported electricity.

General information

7 out of 10 Danes have an hourly pricing on their electricity, and many Danes use digital or smart devices to manage their energy consumption

https://greenpowerdenmark.dk/nyheder/elkunder-flokkes-om-variable-priser

Many Danes follow the electricity price to shift their domestic electricity use from high-price periods to low-price periods. They do this manually by postponing the start of appliances e.g. using programming facilities in the appliances – e.g. dishwashers, washing machines, and charging of EVs. This can also be done in public buildings. However, most public buildings are typically occupied during the period 8:00 – 17:00 – except e.g. hospitals and nursing homes. 8:00 – 17:00 are typically semi-low price periods. Therefore, the savings may not be large enough to justify investments in automation for adjusting the electricity demand according to the electricity price. A better business case is believed to be enabling ancillary services (e.g. for voltage or frequency control but also assistance to reduce bottlenecks in the distribution/local grid) to the grid. These services are of high value as they in principle can prevent blackouts or brownouts. To be able to provide ancillary services there is a need for fast-responding control systems, which can be activated within seconds based on a signal from the grid operators. This demands automated control systems in the building.

Automating the control of buildings for optimizing the energy efficiency of a building can fortunately also be utilized for obtaining energy flexibility. However, a decision layer on top of the control system is necessary as described in Annex 2.

The six case studies indicate that some Danish municipalities are using rather advanced BMS incl. EMS, while others also rely on manual reading of meters. There is thus a need for upgrading the control systems in many public buildings first of all to increase the energy efficiency of the buildings and secondly to be able to offer energy flexibility to the surrounding power grid, but also in the future the surrounding district heating grid, which will utilize large heat pumps. The latter because most public buildings are connected to district heating grids. There are plans for public buildings still heated by oil and natural gas to switch to district heating or heat pumps.

Upgrading the control of energy use in public buildings is implicitly embedded in the 2023 recast of the EU EED and explicitly in the 2024 recast of EPBD. It is thus anticipated that many public buildings by 2030 will be equipped with more advanced measuring and control systems, which may be enhanced further to be able to deliver energy flexibility to the surrounding grids when this becomes necessary.

Annex 1: Method and Data Collection

A total of six buildings were selected by the Danish Energy Agency to participate in the case study, based on the following selection criteria and process:

1. First, an initial examination of the buildings was conducted using the public Building and Residence Register (BBR) and the energy performance certificate for each building.
2. Secondly, a questionnaire was sent out to all the energy managers of each building, to be filled out and returned. The questionnaire focused on the methods and extent of building data usage for daily operations and energy efficiency.
3. Following the return of the questionnaires, virtual follow-up interviews were conducted with each energy manager and the consultants. These interviews lasted between 1-1.5 hours and provided more detailed information based on the initial responses. The focus for the interview was to ensure the interview was subjective and reflected the interviewees' perceptions of the questions and their daily use of the systems, without further verification.
4. The information from all six questionnaires and follow-up interviews were compiled into a single matrix, used to understand and compare the data usage practices for operations and energy-saving efforts across the selected buildings.

The case selection and analysis were conducted between May - November 2024.

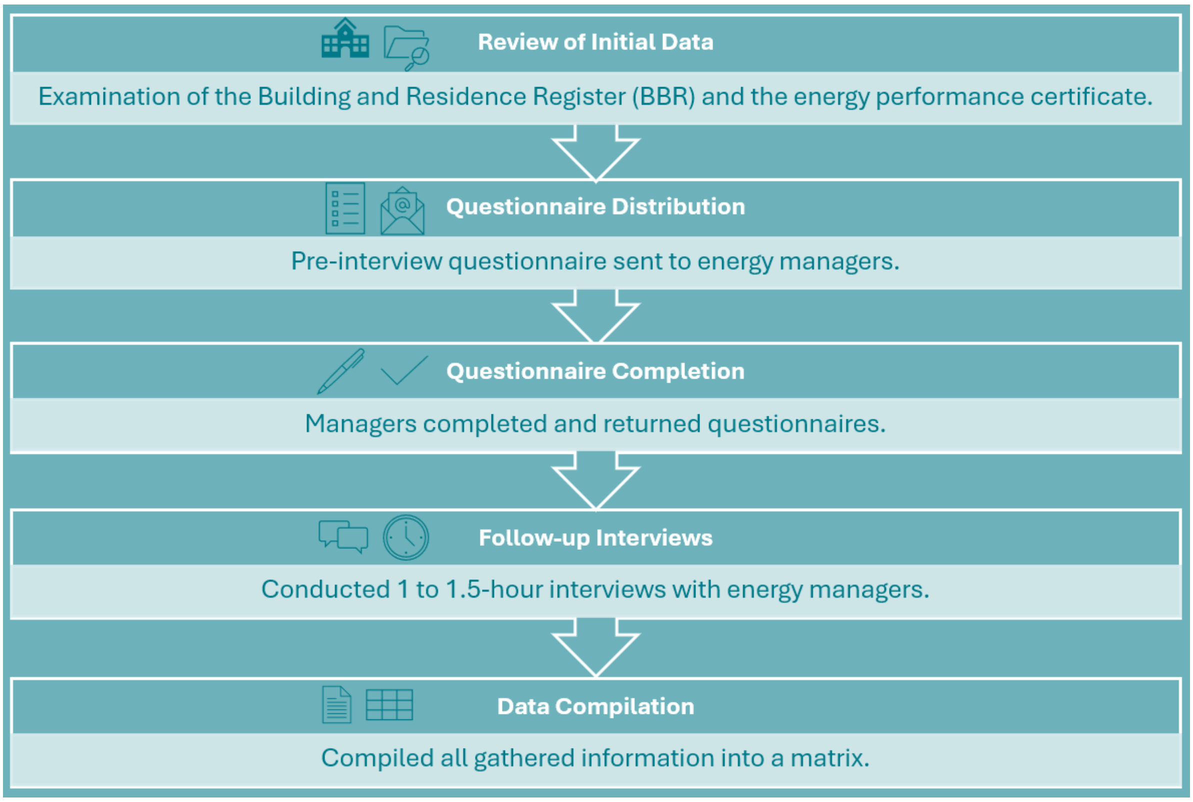


Figure 5. Data collection process of the case studies.

Annex 2: Energy flexibility

The Danish power system has for many years been in a transitions from large central thermal power plants to decentralized power production from district heating systems with gas motors to now more and more wind turbines and PV systems. Fossil fuels are further being phased out for heating and an electrification of the total energy system (also for heating in the form of individual heat pumps, large heat pumps in district heating systems, EVs, etc.) has started. Traditionally the spinning reserves at the large thermal power plant have secured the stability of the power grid, however, with the phase out of the large thermal power plants energy flexibility from other sources are needed, especially because power from wind turbine and PV most often is not in phase with the demand. The demand thus needs to become flexible in order to followed the instant production to on the one hand prevent black outs during shortage of power and on the other hand to avoid curtailment of power during high production periods.

Energy flexibility for the power grid

Buildings are foreseen to play an important role in stabilizing the future power grid. It is often possible to move demand from one period to another – e.g. by utilizing the thermal mass of buildings as storage. Or reduce power demand to ventilation for a shorter period. For a brief introduction to energy flexibility of buildings please see IEA EBC Annex 67[2].

A Danish executive order from December 2013 (based on an EU directive) requests that all billing electricity meters should be remotely readable (also called smart meters) by the end of 2020. The Danish electricity market is liberalized, meaning that the customers freely can choose electricity retailer. Before smart meters, the power utilities only offered flat rate prices for used electricity, as the billing meters were manually read once a year. However, with the introduction of smart meters the electricity retailers can offer different payment schemes, one being dynamic pricing – i.e. pay the actual electricity price hour by hour. The actual production price varies quite much over the day. From January 2023, the end user price for electricity started to vary even more as the DSOs (Distribution System Operators) were allowed to apply more real cost transport tariffs. The cost of transporting electricity in the grid increases with increasing amount of transported electricity.

Figure 6 top graph shows the day ahead (spot) prices hour by hour for August 29, 2024. The prices for August 29, 2024, were revealed on August 28, 2024, at 13:00. Figure 6 bottom graph shows the mean daily spot price for 30 days including August 29. Figure 6 shows that the production (spot) price not only varies over the day but also between days. Low price during the day is caused by much PV electricity in the grid while low mean daily spot price is caused by much wind energy in the power grid.

The top graph of Figure 6 also reflects the pattern of the Danish electricity use over a workday: low consumption during the night, a morning peak followed by a slight reduction during the day, and a high evening peak. The latter is called the "cooking peak" as it occur due to people coming home and starting to cook and switch on other appliances in the home. The cooking peak is defined as the period 17:00-22:00.

This is reflected in the DSO (Distribution System Operator) ToU (Time of Use) transport tariffs as seen in Figure 7. Figure 7 shows an example of ToU tariffs, which better reflects the cost of

[2] https://www.iea-ebc.org/Data/publications/EBC_PSR_Annex67.pdf

transporting the electricity during specific periods of the day, than the formerly applied flat rate tariffs. The highest transport tariff occurs during the hours between 17:00 and 22:00 due to the cooking peak.

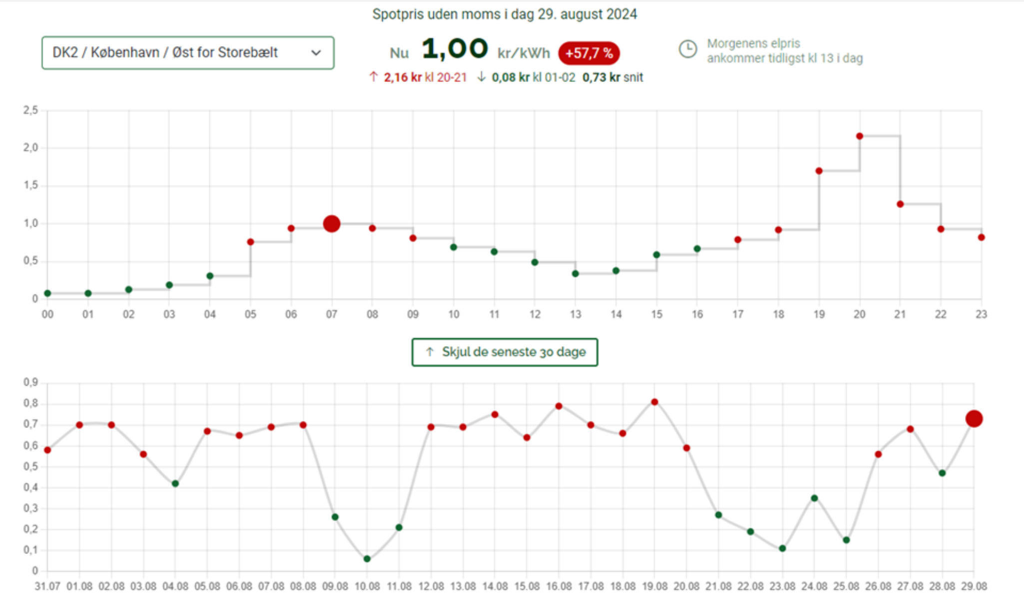


Figure 6. The spot price hour by hour for the eastern part of Denmark for August 29, 2024 and the daily mean sport price for 30 days[3]

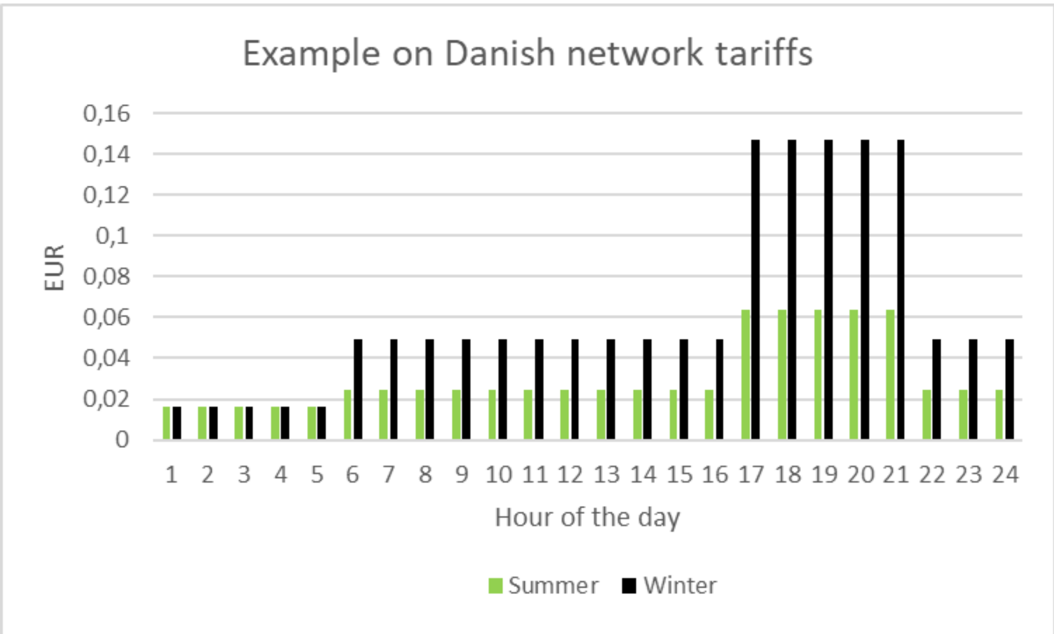


Figure 7. The network (or transportation) tariffs are based on the cost of transportation of the electricity, increasing with higher amount of transported electricity. The transport tariffs are, therefore, higher during the winter than during the summer. The network tariffs are highest during the evening peak, while lowest during the night[4].

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[3] https://www.elprisenligenu.dk/

[4] https://byggeriogenergi.dk/materialer/guide-til-smart-home-og-energistyring in Danish

Danes are well aware of this. A study[5] shows that about two thirds of Danes in the spring of 2023 had a billing agreement with their electricity retailer including dynamic prices for the used electricity. Three out of four of these consumers stated that they had become more aware of when they use electricity. More than half stated that they try to adjust their electricity consumption based on the actual electricity price. This lead to a reduction in the domestic electricity demand during the cooking peak of 10% during the period January-March 2023 compared to the same period in 2020[6]. It was the energy crisis in 2022, which opened up the eyes of Danes to the possibility of shifting their electricity demand away from high-price periods.

The same can be done in public buildings, however, most public buildings are typically occupied during the period 8:00 – 17:00 – except e.g. hospitals and nursing homes. This is as seen in Figure 6 and more clearly in Figure 7 typically semi-low price periods. Therefore, the savings may not be large enough to justify investments in automation for adjusting the electricity demand according to the electricity price.

However, higher cost savings may be obtained if being able to provide ancillary service (e.g. for voltage or frequency control but also assistance to reduce bottlenecks in the distribution/local grid) to the grid. These services are of high value as they in principle can prevent black or brownouts.

To be able to provide ancillary services there is a need for fast responding control systems, which can be activated within seconds based on a signal from the grid operators. This demands automated control systems in the building. However, to participate in this flexible market it is necessary to put large bids in: 1+ MW bids. This amount of energy flexibility is difficult to secure for one building and maybe even for the total pool of buildings in a municipality. There is here a need for an aggregator, which can aggregate many small contributions of energy flexibility and bid this into the flexibility marked.

Fleet operators managing charging stations for EVs are an example of aggregators. Generic aggregation of different types of small amounts of energy flexibility is still at the research and small-scale demonstration level, however, it has been shown that it is possible to aggregate energy flexibility from buildings. Denmark has started to create a new market structure for the power market – called Market Model 3.0[7]. Aggregation of small amounts of energy flexibility is a main component of this work – see also report[8].

There are in principle two ways to control building energy service systems to deliver automated energy flexibility from energy service systems to the surrounding grids (both power and district heating grids).

- Direct control: the aggregator has direct access to control of the energy service systems in the building;
- Indirect control: the aggregator broadcast a control signal, which e.g. can be a price signal. The control system of the buildings receives the signal and optimize the performance of the energy service system in order to minimize the cost of energy (in case of a price signal). The control system does so by dispatching as much as possible of

[5] https://vbn.aau.dk/ws/portalfiles/portal/560988712/Oplevelser_af_energikrise_i_Danmark.pdf. in Danish
[6] https://energycentral.com/c/em/flexible-demand-denmark-conversation-claus-krog-ekman
[7] https://ens.dk/en/supply-and-consumption/market-model-30
[8] https://www.researchgate.net/publication/363331559_Market_Model_30_A_New_Ecosystem_for_Demand-side_Flexibility_Aggregators_in_Denmark

the energy demand from high price periods to low price periods under the constrains that the indoor climate remains satisfactory.

Indirect control is the preferred option for smaller amounts of energy flexibility like from buildings, as no direct communication with the building is needed, which reduces the need for cyber security measures and it requires less traffic on the internet.

However, automated response to a signal for providing energy flexibility, while still maintain the functions and indoor quality in the buildings, requires:

- Main states in the building need to be measured online:
  - Meters on energy systems for determination if energy can be shifted in time. But also to gain knowledge of the typical variation over the day, so models for the dispatch of energy use can be created;
  - Indoor environment quality: e.g. temperature for ensuring that the indoor temperature does not fluctuate too much and stays within a defined comfort range. PIR sensors: to define the presence of people. CO_2 sensors: to ensure that the ventilation flow rate does not get too low. Etc.
- The energy service systems need to be controlled based on the received signal from the aggregator and the actual state of the buildings:
  - A simple control is to react directly to the signal at a specific time – e.g. turn down the ventilation rate or change the set point temperature in the rooms;
  - A more advanced control has knowledge on how the building will react to a series of control signals from the aggregator. E.g. if a high price period is forecasted, a cooling system may e.g. lower the room temperatures to the lower threshold of the wished temperature range making it possible to switch off the cooling system for a longer period during the high price period. The building will here be able to deliver energy flexibility for a longer period and thereby save more;
  - For the latter the knowledge about the reaction of the buildings can be obtained from utilization of historic data, which are all the measured states over a long period together with logged weather conditions and coincident previous series of control signals from the aggregator. The knowledge can e.g. be imbedded in a MPC (Model Predictive Controller);
  - This requires that measurements are logged and stored.
- The measured data need to be reliable and thus be of a sufficient high quality so that the use of these do not lead to wrong decisions:
  - Check that the measurement devices are located where they are supposed to
  - Check that the meters and sensors give correct readings;
  - The measurements needs to be stored with labeling that cannot be understood.

A more thorough descriptions on the requirements for smart buildings can be found on IEA EBC Annex 81[9].

Energy flexibility for district heating (DH) grids

For most Danish building the heating demand is higher than the electricity demand. This goes also for most public buildings. More than 65% of Danish homes are heated by district heating, - a number which is foreseen to increase above 70% in 2030. Public buildings are also mainly

[9] https://annex81.iea-ebc.org/

heated by district heating, and plans for phasing out oil and natural gas have been prepared. These buildings will switch to district heating or heat pumps. If heated by a heat pump energy flexibility can be obtained via an aggregator as explained above.

Not all district heating customers have a smart heat meter, however, a roll-out of these meters is ongoing based on an EU directive. It is mainly in the larger DH systems in larger cities which are front runners here.

The energy mix in the 400+ Danish DH systems differs much. There is a focus on utilizing excess heat for district heating. It started in large cities with large thermal power plants where the cooling of the steam from the turbines was utilized for district heating, however, excess heating from incineration or industry including data centers is also utilized. Biomass is currently utilized in many district heating systems. In more rural areas solar thermal systems are also often conceded to the DH system. Some district heating systems even have electrical boilers, which are switched on when the electricity price from time to time becomes negative due to very high wind or solar drivel power production.

Do district heating systems need energy flexibility? Currently to some extent but in the future very much:

- Current situation: the main demand peak in DH systems is in the morning, and when buildings with night setbacks of the room temperature need extra power to heat up the buildings. Here there is a need for back-up boilers which typically are expensive to run – e.g. oil or gas boilers. Otherwise night setbacks should be avoided, and the customers can have domestic hot water tanks, which can be heated during the night;
- In the future: due to the electrification of the Danish energy system a large part of the heat in district heating systems will be generated by large heat pumps. These heat pumps need to be run flexibly to stabilize the power grid. Flexibility can be obtained by large (water) buffer tanks at the plants, however, the thermal mass of the buildings can also be utilized for gaining flexibility.

Obtaining energy flexibility from buildings for district heating systems requires similar instrumentation and control systems in the buildings, as for obtaining an energy flexibility electricity demand.

A DH system using heat pumps can offer a larger amount of energy flexibility than a single building. The energy flexibility from DH systems may, therefore, be of a higher value for the power grid and may be easier to control.

More information on demand management of buildings in DH system can be obtained on IEA EBC Annex 84[10].

[10] https://www.iea-ebc.org/projects/project?AnnexID=84