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European Climate Initiative (EUKI) Municipal energy planning and energy management experience in Germany

conducted on behalf of
Deutsche Gesellschaft für Internationale
Zusammenarbeit (GIZ) GmbH
Dag-Hammarskjöld-Weg 1–5
65760 Eschborn

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Forschung, Entwicklung,
Demonstration und Beratung auf
den Gebieten der Bauphysik

Zulassung neuer Baustoffe,
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This report comprises
53 pages of text
5 tables
13 figures

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Content

1 Introduction

The project "Municipal energy management systems (19_065)", funded within the framework of the European Climate Initiative (EUKI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), aims to promote municipal climate protection in Bulgaria by developing an energy management system with complementary implementation tools and by building up planning capacities in municipal administrations.

In contrast to Bulgaria, Germany has a long tradition of implementing energy management systems for municipal energy planning and implementing local long-term energy and climate strategies. Activity 1 of work package 1 compiles the German experience in municipal energy planning and energy management. The analytical report shall be the starting point for the development of an energy management system for Bulgarian municipalities in activity 2 and for the development of an energy management toolbox in activity 3 of work package 1. The focus of the implementation model is on public buildings and public lighting.

In work package 2, which builds on these activities, the newly developed toolbox will be introduced and evaluated in three pilot cities. The development of a financial instrument for Bulgarian municipalities for the introduction of the new energy management system is carried out in work package 3, while the final work package 4 serves to raise awareness for municipal energy management in Bulgarian municipalities.

Besides Fraunhofer Institute for Building Physics IBP, the Bulgarian Center for Energy Efficiency (EnEffect) and the National Trust EcoFund (NTEF) of Bulgaria are involved in the project.

The present analysis report provides an overview of best practice examples in German municipalities with a focus on the most successful energy management systems, technical solutions and implementation approaches, including an evaluation of organizational structures, planning processes, instruments used and financing possibilities. Chapter 2 describes the most important components of municipal energy management in Germany. Chapter 3 presents three municipalities in southern Germany that have introduced successful municipal energy management actions. A closer look at individual aspects of municipal energy management is taken in chapter 4 and the relevant features and challenges in the three municipalities studied are discussed. As a result recommendations are derived how the approaches from Germany can be adapted to the conditions and requirements in Bulgaria in chapter 5.

2 Energy management system

The cost for energy supply of municipal properties is a significant item in public budgets. In Germany, the energy costs of public buildings amount to more than 4 billion euros per year [1].

Energy management should therefore be an integral part of municipal building management. It supports the municipality in the rational use of energy and water, reduces the financial burden on municipal budgets and contributes to climate and environmental protection. In this way, local authorities can not only set an example, but also significantly reduce their building management budget [2].

2.1 Tasks of municipal energy management

Municipal energy management covers a wide range of tasks, which is modularly structured and can be successively expanded. The central component of energy management is energy controlling, which provides the knowledge base for all other task areas such as operational optimization, energy procurement or building analysis and development of energy concepts (see Figure 1).

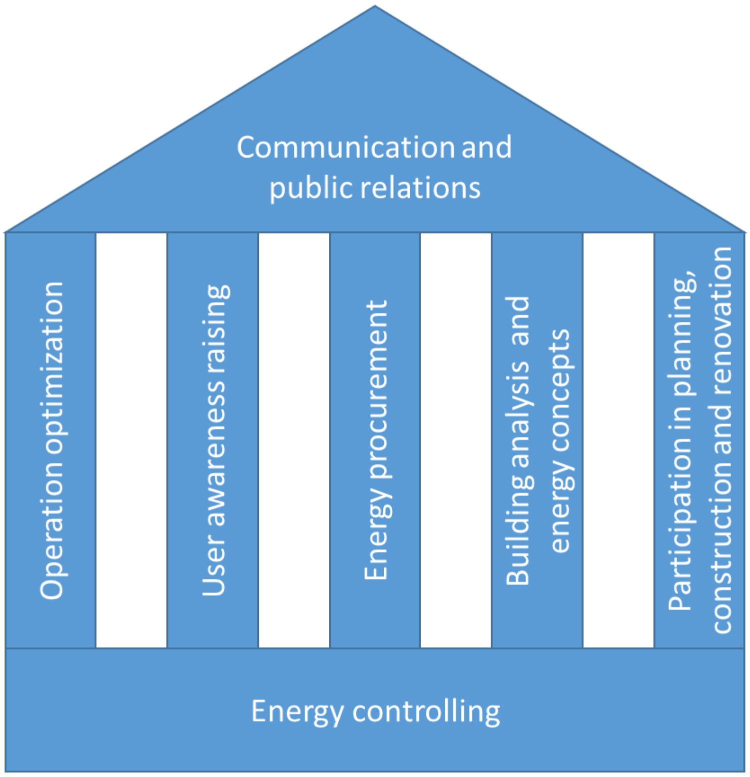

Figure 1:
Tasks of municipal energy management [2].

2.1.1 Energy controlling

Energy controlling refers to the systematic recording and analysis of electricity, heat and water consumption and the resulting costs, as well as the ongoing documentation of system performance and maintenance intervals. The energy consumption data form the basis for the optimization of energy supply contracts, the planning, implementation and success control of energy saving measures, user awareness and the preparation of energy certificates and energy reports (see also [3]).

In order to establish efficient energy controlling, the consumption data should be recorded at least annually, if possible monthly. In high-consumption properties, a finer temporal resolution should also be provided if necessary. In principle, the consumption data can be read off manually by the responsible caretaker, but automated data acquisition with data loggers or, in the case of larger properties, by installing a building management system is much more convenient and less prone to errors. The data logger systems usually contain an internet-based software solution that enables the automatic daily query of the devices. With these tools, the consumption data can be continuously recorded and visualized. An automatic limit value monitoring system allows irregularities to be reported immediately, so that the employee responsible can take care of solving the problem at hand [4]. It is advisable to record the consumption data manually from time to time in order to detect incomplete and incorrect measurement data.

In order to make consumption data from different years comparable with each other, a so-called weather adjustment of the heating energy consumption must be carried out. By allocating building areas, it is also possible to create area-specific energy consumption figures, which make it possible to compare buildings of different sizes. Dependent on the characteristics used in a country and the available information the net floor area can be used as the reference area, alternatively the gross floor area or the cleaning areas.

Depending on the issue at hand, energy consumption can be visualized in different types of diagrams. For the benchmark analysis, usually column or bar charts are used, in which the energy consumption figures of buildings of the same type are displayed next to each other and reference values are compared. By means of this presentation, outliers in energy consumption can be identified at first glance and possible savings potentials can be roughly estimated. Either fixed values from surveys [5] are used as reference values or new average values are formed annually from available consumption data.

A grid evaluation of the energy consumption is carried out by a carpet-plot. The diagram has two time axes with different resolutions (e. g. days on the x-axis and hours on the y-axis). The characteristics of the energy consumption at the respective point in time are displayed in color-coded form. The application of the consumption data in temporal resolution allows to recognize patterns in large amounts of data and to identify the occurrence of minima, maxima and regular events.

With a Sankey-diagram, energy flows in larger properties can be visualized in proportion to quantity. The diagram consists of arrows that show the energy flow between two processes (e. g. power generation from photovoltaics and power consumption for cooling) to scale. Instead of confusing tables with statistical data, the Sankey-diagram clearly shows the proportions of the various energy sources, from their origin, through conversion, to the use of the energy.

The ordered annual load curve is a line diagram that shows the thermal power demand of a property depending on the frequency of occurrence within a year. It can be used to determine the utilization rate of building services and to dimension heating systems. Typical fields of application are the dimensioning and economic evaluation of combined heat and power units (CHPs) or the dimensioning of thermal storage units.

In addition to the ordered annual load curve, load profiles for electricity consumption are also of great importance for the dimensioning of CHPs. The load profile shows the temporal course of the purchased electrical power over a day. The load profile is usually subject to strong daytime fluctuations, which in turn are dependent on the day of the week and vary according to season. On the basis of the load profile, base load and peak load can be identified and, based on this, load peaks can be shifted to off-peak periods.

2.1.2 Operation optimization

The operational optimization of building services engineering is generally a very effective measure to reduce the energy consumption of heating, domestic hot water generation, ventilation and air conditioning. A prerequisite for operational optimization is a survey of the utilization requirements in terms of utilization times, air exchange rates, room air temperature and indoor air humidity. Once the user requirements are known, they can be compared with the on-site setting parameters.

To be able to make the appropriate settings, first the available technical documents such as general arrangement diagrams, operating instructions, inspection documents and maintenance records should be consulted and the responsible person should be familiar with the components and functionalities of the system technology. In the course of an inspection, the components of the building services are located and missing information on the system technology is added.

If the system technology does not include sufficient measuring equipment, mobile data loggers can be used to record and evaluate the operating status such as set operating times and system parameters, over a representative period of time.

The optimization of the system operation is carried out systematically by a continuous adjustment of the control parameters. In order to keep the changes in settings and their effects on indoor climate and energy consumption comprehensible, documentation of the adjustments must be included in the technical documentation.

In the case of heating, there is generally considerable potential for savings by reducing room temperatures during periods of non-use (night hours, weekends and holidays). Significant savings potentials in heating requirements can also be achieved by reducing the flow and return temperatures, readjusting the heating curves and adjusting the power requirement of the heating circuit pumps. A pre-requisite for the optimized operation of water-bearing heating systems is hydraulic balancing. Here, the flow rates and flow temperature are regulated in such a way that each room is supplied with the necessary amount of heat to reach the desired room temperature.

With mechanical ventilation, it is essential to adapt the operating times to the actual presence of the users. In order to reduce the energy consumption of the fans, the volume flows of supply and exhaust air must be reduced to the hygienically necessary level. As a rule, halving the air volume flow leads to a reduction of power consumption for air transport to one eighth.

In cooling, minimizing the cooling loads plays a key role. This includes both activating the sun protection to keep solar inputs as low as possible outside the heating period and reducing internal loads from lighting and electrical devices.

The involvement of technical operating staff and caretakers is important for continuous operational optimization. As a rule, they are the ones who know the building, system technology and user requirements best. Regular training of the caretakers and the technical operating staff as well as the establishment of an exchange of experience are important accompanying instruments to achieve a successful operation optimization of building services.

In addition to optimizing operations, there are also various low-investment measures that could be initiated by energy management and with which savings potential could be tapped in the short to medium term. In some municipalities, energy management has its own budget available for the realization of quick wins. Common low-investment measures include

- Installing thermostatic valves to control heat transfer
- Performing a hydraulic balancing in the heating distribution network
- Replacement of old, unregulated heating pumps with efficient pressure-controlled pumps
- Thermal insulation of accessible heating pipes

- Retrofitting of seals on windows and doors
- Replacement of inefficient lamps and deactivation of superfluous lamps
- Use of switchable socket strips for electrical consumers to minimize standby consumption

2.1.3 User awareness raising

Noticeable savings can be achieved by positively influencing user behavior. Experience from completed projects shows, that up to 20 % savings can be achieved in public buildings by adapting user behavior without major investment or loss of comfort [6].

Adaptation of user behavior is associated with a change in habits, which generally requires a continuous sensitization process. In order to keep the topic present in the minds of the users, regular communication in the form of recurring actions and events as well as reminders for everyday situations is necessary.

A prerequisite for adapted user behavior is the awareness of energy-relevant contexts. This includes information on climate change and energy shortages, an awareness of energy consumption and energy costs as well as a sense of personal responsibility and an understanding of personal options for action with regard to climate protection.

The possibilities for users to contribute to energy saving are manifold and range from the efficient use of electrical appliances and lighting, through adapted ventilation and heating behavior, to the economical use of tap water.

A crucial success factor for a lasting user awareness is to motivate the users. This includes not only the visualization of achieved successes. The setting of financial incentives has proven to be particularly motivating, e. g. in the form of participation in energy cost savings achieved.

Among the most important measures for successful user awareness raising are:

- Administrative instruction on the economical use of energy
- Annual announcement of property-related energy consumptions with classification to user-specific comparative values
- Personal advice on user behavior by energy officers as well as regular, target group-oriented sensitization meetings
- Information and action days with exhibition, join-in activities and information material

- Reporting on actions and results on the website, in the official journal of the city and in the local press

2.1.4 Energy procurement

In addition to measures for the rational use of energy, the efficient purchase of energy represents an important aspect of reducing energy costs. A comparison of the energy costs of 30 German cities shows, that despite the same purchase quantities and similar load profiles, there are sometimes significant price differences [7]. Depending on the energy source, the price range between the cheapest and most expensive energy price is more than 100 %. But the choice of energy source also has a considerable influence on energy costs. If, for example, a wood chip boiler is compared with an oil boiler, the pure fuel costs for one kilowatt hour of heat in Germany differ by a factor of 2.

Based on a rough analysis of the existing energy supply contracts, the energy cost saving potentials of a municipality can be estimated. For this purpose, mixed prices are formed for each medium (electricity, heat and water) from the total costs and the total consumption. A portfolio analysis can thus be used to identify energy supply contracts that are associated with particularly high energy costs. An additional gain in knowledge can be achieved by comparing energy prices with other, comparable municipalities. To establish reference values, the municipal energy costs are to be compiled in a national study.

A further aspect of optimizing the energy supply is a review of the connected loads in the supply of mains energy sources. Since the costs for the energy infrastructure are passed on to the customer via the basic price depending on the connection capacity, over dimensioning leads to unnecessary additional costs. On the basis of existing energy consumption values, which must be available at least monthly, and the corresponding outside temperatures, the heating load can be roughly determined and compared with the provided power and adjusted if necessary. By optimizing the load profile, the connection load of electricity can also be reduced. For this purpose, a detailed study should be carried out to analyze which electrical loads can be shifted in order to alleviate load peaks.

By switching the electricity supply to green electricity, the CO_2-emissions of public properties can be reduced considerably, thus not only contributing to climate protection but also fulfilling the role model function of the public sector. In principle, local authorities can impose environmental requirements on their procurement items. According to the case law of the European Court of Justice, this principle is also applicable to the tender for the supply of green electricity, subject to compliance with certain conditions. These include a direct link between the environmental characteristics and the subject of the contract, no obstruction of market access and discrimination against tenderers, no unrestricted freedom of choice for the contracting authority, a description of the requirements in the contract notice and effective verification of the information contained in the tenders [8].

In addition to the purchase of green electricity, the own energy generation from renewable energy sources or the provision of areas for solar plants for private investors or energy cooperatives are also opportunities to promote the expansion of renewable energies through municipal action, to open up new sources of income and to reduce dependence on energy imports.

2.1.5 Building analysis and energy concepts

When analyzing the municipal building stock, the energy consumption data are used to identify the municipality's main consumers. A suitable method for this purpose is, for example, a power-heat-diagram [3] or a 4-field-matrix (see Figure 2), in which the absolute consumption of the properties and the deviation from the reference value of the building type is compared. The advantage of the power-heat-diagram is, that the specific power and heat consumption and the share of energy costs can be shown together in one diagram. Due to its 3-dimensionality, however, the power-heat-diagram quickly loses its clarity, which is why it is particularly suitable for small and medium-sized municipalities. The 4-field-matrix, on the other hand, can be used regardless of the number of properties, but electricity and heat are considered separately.

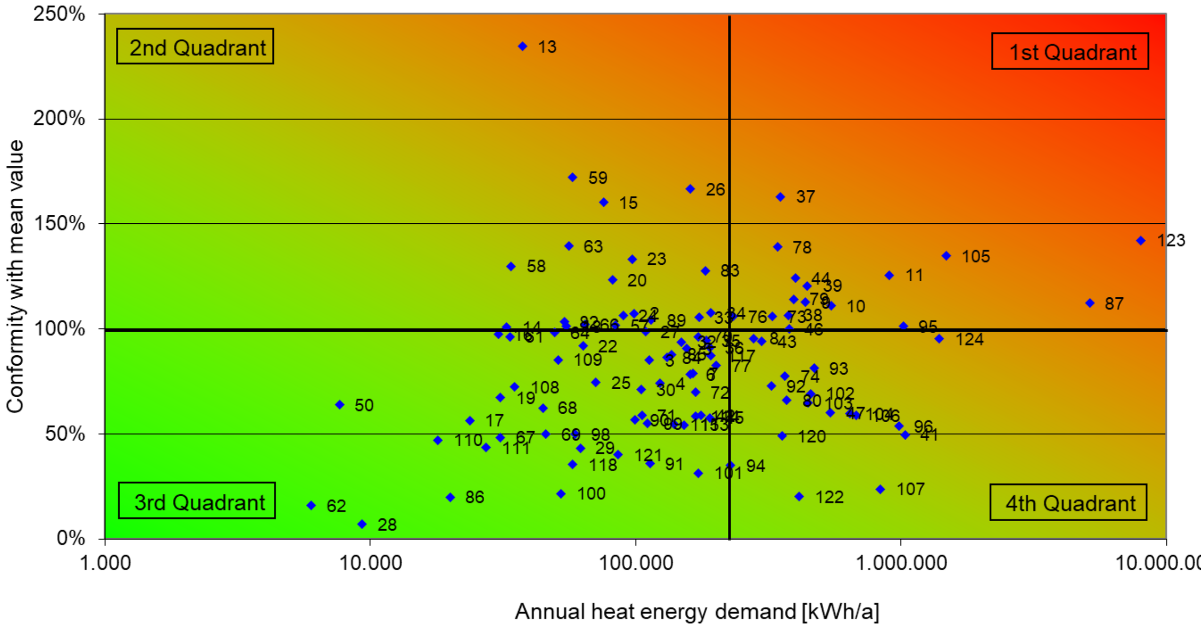

Figure 2:
4-Field-Matrix for identification of properties with high energy saving potential [9].

In a next step, the building-specific savings potential is roughly determined by comparing the object-specific consumption values with use-specific reference values. From the deviation between the characteristic values and the reference values, first insights into the existing savings potential are possible. However, it must be taken into account that conspicuous characteristic values can also result from deviating user behavior (e. g. regular evening events) and do not necessarily indicate a savings potential.

Based on this preliminary work, a prioritization of the properties is carried out. In addition to the absolute energy costs and the estimated savings potential, maintenance requirements, the multiplication potential, the complexity of the property and the motivation of the operating staff must also be taken into account for the prioritization.

Energy concepts are an important basis for a structured approach to modernizing the municipal building stock. In addition to an overall concept that outlines a general energy and climate protection strategy, object-related energy concepts take up these objectives and show feasible solutions for upgrading the structural and technical substance of the individual property.

The basis for the preparation of energy concepts is an inventory of the building envelope and building services as well as a survey of object-specific conditions. For this purpose, existing planning documents are reviewed and the information is checked and supplemented during an on-site inspection of the properties. The on-site inspection should also include a documentation of serious structural and technical deficiencies that require immediate action.

Based on the inventory, an energy evaluation of the current status is prepared. For this purpose, a calculation model is created for the property and an energy balance with evaluation of the building-specific energy use is carried out. To calibrate the calculation model, a comparison with the energy consumption data is usually necessary. Weak points can be identified from the results of the current state analysis and energy-relevant components and technical systems can be evaluated with regard to their energetic condition. Finally, measures to reduce consumption and increase efficiency can be derived from these findings.

With the help of the building model, a quantitative analysis of the optimization potential is possible. Taking into account the reduction potential, the economic efficiency, the structural urgency and the technical feasibility, a prioritization of the identified measures can be made and a concrete renovation roadmap for the respective object can be derived.

The development of a guideline for the preparation of energy concepts and renovation roadmaps can contribute to quality assurance by setting requirements for the methodological procedure, the use of assumptions and default values as well as a standardized documentation of results.

2.1.6 Participation in planning, construction and renovation

A key instrument for implementing energy-efficient new construction and refurbishment projects is the municipal setting of energy guidelines and standards for planning. A distinction can be made between essential targets and structures for energy efficiency and energy supply (guidelines) and detailed structural and energy planning instructions for municipal departments and external planning offices [10].

An energy guideline should be adopted by the responsible local political body (e. g. municipal council). In addition to setting key targets for energy efficiency and the use of renewable energies, it should also regulate responsibilities and tasks within the municipal administration. The central element of the energy guideline are energy efficiency standards for new buildings and renovation. Exceptions should only be made in justified cases, e. g. in the case of very short-term building use or historic listed buildings.

Planning instructions, which provide detailed specifications on insulation material, insulation thicknesses or characteristic values of technical installations, must be developed and agreed with the committees of the responsible administration and in dialogue with the specialist colleagues involved in the planning and operating divisions. Common planning instructions include, for example, maximum values for heat transfer coefficients, limiting the proportion of glass surface, avoidance of active cooling and humidification, using sustainable, durable, low-maintenance materials, prioritizing the use of energy sources or recommendations for the commissioning and monitoring of new systems. A compilation of the planning requirements in the form of checklists has proven to be practicable and can greatly facilitate application and verification [10].

Already in the early planning phases of new construction and refurbishment projects, decisions are made which have a significant impact on future energy consumption and the associated operating costs. By involving energy management as early as the determination of requirements, a planning basis for decisions on the necessity of investments can be developed which also takes sufficient account of energy-related aspects. Especially in existing buildings, the findings from energy management can be profitably applied. Energy management usually has building-specific information and energy data that can provide a good basis for comparing variants and for the economic analysis of measures to reduce consumption, as well as for the use of renewable energies or the improvement of the energy efficiency [3].

The relevant information includes, in particular, energy consumption data and load profiles, usage times and occupancy densities, existing energy-related and structural weak points, characteristic values for system technology and control parameters of building automation as well as a designation of main consumers and optimization potential.

2.1.7 Internal communication and public relation

The preparation of an annual energy report, which shows the development of consumption in the municipal properties and classifies it on the basis of a benchmark analysis, is an essential element of energy management. The regional energy agencies in Germany provide sample energy reports which municipalities can use as a guide for preparing their reports [11].

The typical structure of an energy report includes a summarizing evaluation in part 1 in order to provide a quick overview of the most important results, especially for decision-makers. part 2 describes the decision-making basis of municipal energy management and explains responsibilities and areas of responsibility. part 3 provides an overview of the consumption and cost structure of all properties, with evaluation of the properties using energy parameters and analysis of the development over time. In part 4, individual properties are examined in detail and a rough analysis of the building services and building fabric is carried out. Based on this, the following chapter presents the results of detailed analyses and gives an overview of identified measures, investment and financing plans as well as steps for implementation. Based on this, the following chapter presents the results of detailed analyses for selected properties and provides an overview of identified measures, investment and financing plans, and necessary steps for implementation. Finally, the measures implemented during the reporting period are described and the savings achieved are presented.

In the case of municipalities with a large building stock, it is not practicable to take a comprehensive view of all individual properties in the main report. Instead, only the most important individual properties are presented in the main report; the remaining properties are dealt with in separate property-related energy reports. When using professional software for energy controlling, a function for the standardized preparation of annual cross-property and monthly property-related energy reports is usually already included. Alternatively, services offered by local energy suppliers and energy agencies for the preparation of energy reports can also be used.

In addition to the energy report, regular discussions with technical operating staff and caretakers as well as the provision of information to committees and technical commissions, are of great importance for the success of municipal energy management. The top management should be informed about organizational and structural problems and obstacles at regular intervals and should jointly consider possible solutions.

The posting of a quarterly brief energy report is a suitable means of informing the users of municipal properties. In the case of properties with particularly high energy consumption, consideration should also be given to providing users with up-to-date information at least on a daily basis. This could be done, for example, via a screen in the entrance area of the property.

Following the motto “Do good and talk about it”, the work of municipal energy management should also be made known to the general public. This includes, for example, publicizing activities on the city's own website, in the official journal or in the local press. The experiences and findings of municipal energy management can thus be transferred to companies and private households, in order to increase the acceptance of investments in municipal energy management in the population and to fulfill the role model function of the municipality in the case of climate action. In addition to using the usual communication channels, a regular direct exchange with multipliers such as chambers of craftsmen and engineers, associations or consumer protection centers is a suitable way of publicizing the work and results of municipal energy management.

2.2 Anchoring in the municipal administration

Municipal energy management only functions as a cross-sectional task in cooperation with the management level and the individual departments of the municipal administration. For this, sensible task distribution and functioning connections are of great importance. The energy manager has the task of coordinating municipal energy management as a cross-sectional task, monitoring the functionalities of the links with the specialist levels, ensuring that energy management runs smoothly and initiating any necessary changes in the organization and structure [3].

The following connections within the municipal administration are of greater importance for a successful energy management:

- Political committees: decision-making and control body
- Mayor: assigning and prioritizing resources
- Office and section management: key point for effective cooperation
- Structural engineering office: planning and implementation of new construction and renovation as well as planning specifications and quality assurance
- Property management: energy supply contracts, maintenance contracts, repairs, usage contracts and renting
- Administration operating staff: caretaker and technical staff

2.3 Costs and personnel expenses

The detection of weak points and the implementation of low-investment measures can save up to 30 % of energy consumption in the first years after the introduction of a municipal energy management system [2]. Experiences of various cities show, that savings achieved through efficient energy management usually exceed the necessary expenditure many times over (see Table 1). Energy controlling in particular has a particularly favorable cost-benefit ratio. For every euro invested, savings of 5 to 10 euros can be achieved.

However, both energy controlling and operating optimization of the building services are tasks that must be continued on a long-term basis. If these tasks are temporarily suspended, increases in energy consumption can usually be observed. In a school in Stuttgart, for example, energy consumption increased by 20 % over a period of four years without energy controlling [12].

Table 1:
Cost-benefit-ratio of different parts of municipal energy management [4].

	Saving potential [%]	Cost-benefit-ratio [-]
Energy controlling	> 5	1:5 to 1:10
Operation optimization	> 15	1:3 to 1:5
Investment measures	> 30	1:1 to 1:2

The personnel expenditure for municipal energy management is strongly dependent on the range of tasks and the size of the municipality. While in small municipalities with up to 50,000 inhabitants, energy management is still handled on a part-time basis and focuses primarily on energy controlling and operational optimization, in medium-sized towns with up to 100,000 inhabitants, the tasks taken over by municipal energy management are increasing significantly. In addition to the basic tasks, user awareness, energy-related building analysis and the preparation of energy concepts for buildings, as well as internal communication and public relations, are becoming much more important. The personnel required for this is one to one and a half full-time positions [3].

From a size of 100,000 inhabitants upwards, municipal energy management generally covers the entire range of tasks. The personnel costs then result primarily from the net floor space to be managed. A survey of 28 German cities shows that with a net floor area of 500,000 m², an average of four full-time positions are sufficient, while the personnel requirement rises to six full-time positions for a net floor area of one million square meter. Every further doubling of the net floor area adds another three full-time positions [13].

Experience shows, that a division of tasks on several shoulders and an interdisciplinary composition of the energy team have a positive effect on the success of municipal energy management. The players in municipal energy management are composed of the energy manager, who is responsible for internal project control, communication, information and user awareness raising, the energy technician, who is responsible for optimizing the operation of building services and involving the caretakers and operating personnel, the caretakers, who are familiar with the buildings and technical facilities on site, and the management level, which strategically supports the municipal energy management and provides the necessary resources.

2.4 Tools and services

Especially in small and medium-sized municipalities, the available resources are limited, which is why external support is usually needed. An interesting solution for smaller municipalities with limited personnel resources is inter-municipal co-operation with neighboring municipalities or at the district level. For example, energy managers can be jointly employed or the procurement of energy and energy services can be carried out jointly [14]. The involvement of committed citizens can also be a way of distributing the tasks of municipal energy management over several shoulders. For example, the retired heating engineer can help to optimize operations or a former teacher can help to raise user awareness.

The external support also includes offers from energy agencies such as working aids, further training courses, on-site advice and coaching as well as the placement of planners, tradesmen and auditors. At state and federal level, subsidies are provided for personnel, measuring technology, energy controlling software and savings projects. The following is an overview of the most important guidelines, working aids, software products and quality assurance systems available in Germany in the field of municipal energy management.

2.4.1 Guidelines and working aids

In Germany, there are various guidelines, working aids and recommendations for action to get started in municipal energy management. The starter package of the Climate Alliance and "Deutsche Umwelthilfe" (German Environmental Aid), for example, offers a compact introduction to the topic of municipal climate protection. Chapter 1 describes recommendations and tips for getting started in the field of energy saving and municipal energy management, supplemented by organizational tips and a selection of low-investment measures [4].

Since 1996, the German Association of Cities and Towns' "Energy Management" working group has been working on guidelines for municipal energy management. The guidelines are written in a generally comprehensible and coherent manner and are available free of charge to interested cities and municipalities in Germany and abroad. Currently, 20 publications are available on the topics of organization, energy controlling, reporting, public relations, technical information, operational information, financing and procurement. In addition to general information and recommendations, a wide range of examples from the participating municipalities are also presented and the experience gained is shared with interested municipalities.

In the basic module "Energy Management" of the State Institute for the Environment, Measurements and Nature Conservation of Baden-Württemberg (LUBW), practical experiences and successful examples from municipalities are presented and intersections with other management systems for municipalities such as the Eco-Audit or "European Energy Award" are highlighted [15]. Basic information on energy management in public buildings has also been compiled by the Working Group for Mechanical and Electrical Engineering of State and Municipal Administrations [8].

With "dena-EKM", the German Energy Agency (dena) offers a low-threshold, cost-effective and open offer for systematic energy and climate protection management for small and medium-sized municipalities. The accompanying brochures [16], [17] describe the establishment of structures and the implementation of processes and illustrate the procedure with suitable examples. In addition, the Energy Management and Energy Performance Contracting Guide [18] provides information on the introduction of energy performance contracting as an alternative financing instrument for contractually guaranteed CO_2 savings.

A guideline for the introduction of an energy management system for municipalities according to ISO 50001 was developed within the framework of the European research program Horizon 2020 [19]. The guide explains how to manage energy according to ISO 50001 and describes the practical implementation within a municipality. The Federal Environment Agency of Germany (Umweltbundesamt) provides a checklist for the introduction of an energy management system to verify whether the requirements of ISO 50001 are met [20].

The tool "kom.EMS" used by different energy agencies from Germany is a municipal translation of the industry standard ISO 50001. The tool can be used to examine proposed measures and implement the measures in the field of action "municipal buildings and facilities" of the European Energy Award. The "kom.EMS guideline" [3] addresses all actors of energy management in the municipal administration and shows the most important challenges and useful proposals for solutions in concrete process phases from the initiation to the establishment and the consolidation of municipal energy management. In addition to the guide, working aids and materials are made available in the "kom.EMS knowledge portal" [21]. This includes, for example, job descriptions for energy managers and energy technicians, a construction kit for the internal organization, sample reports and sample contracts, checklists, data entry forms and calculation tools as well as a compilation of minimum requirements and criteria for the procurement of an energy controlling software. With the freely accessible working aid "kom.EMS Check" [21], municipalities can check the quality of their existing energy management on the basis of 33 questions and receive an analysis of strengths and weaknesses in the respective fields of action based on their answers.

2.4.2 Energy controlling software

The choice of a suitable energy management software contributes significantly to the success of energy management. The main purpose of energy management software is to support the user in energy controlling and to automate work processes as far as possible. The typical functions [22] of an energy management software are:

- Systematic recording and documentation of energy consumption
- Data check for plausibility and consistency
- Inclusion of moderating circumstances (degree day number, weather data, public holidays, operating hours)
- Aggregation of measurement data and standardized evaluation (target-performance comparison, time series comparison)
- Creation of key figures and provision of reference values for benchmarking
- Visualization of energy consumption and reporting
- Warning mechanism for abnormal consumption
- Control of subsequent systems and consumers

In addition to energy consumption and thermal and electrical performance, various software products also offer the possibility of recording status data of the building services. These include, for example, temperatures, air humidity, volume flows, CO_2 concentrations, illuminance, valve positions, etc. This additional information is particularly relevant for the monitoring of complex properties with high energy consumption and comprehensive, automated data acquisition.

The data import into the software is usually automated by connecting the data loggers to the central evaluation unit. In principle, most software products also allow manual import of data (e. g. MS Excel spreadsheet) or manual input of consumption data.

All common file types are usually available for data export. The output options range from the automated generation of energy reports or the output of consumption-oriented energy certificates for individual properties to the graphic display of specific test results. Common forms of result visualization include column or bar charts, pie charts, annual load curves and load profiles. Some of the software products also offer Carpet-Plot and Sankey-Diagram as forms of visualization as well as the possibility to display results of a regression analysis or cluster analysis (e. g. Boxplot, regression curve).

A particularly helpful function is a warning mechanism in the event of abnormal consumption. For this purpose, object-specific threshold values are usually defined, and if these are exceeded, a warning signal is sent to the responsible operational personnel. However, in order to define the threshold values, a time-consuming manual review of measurement data is necessary.

Without setting up target and threshold values, self-learning systems can automatically determine patterns from the consumption data (big data) and detect abnormalities in energy consumption. Behind this artificial intelligence are algorithms that detect and classify abnormalities, events, trends and drifts in the automatically recorded measurement data. Big data also offers the possibility of predicting malfunctions and failures of systems, thus enabling demand-oriented maintenance, which can contribute to maximizing maintenance intervals and minimizing maintenance effort [23].

2.4.3 Management and quality assurance instruments

Certification generally provides evidence that the requirements of a system have been successfully implemented in an organization and thus serves in particular to ensure quality. The image of a municipality can be improved and the certification can be used for public relations by making the municipal commitment visible in the fields of energy management and climate protection. The most important certification instruments in the field of municipal energy management and municipal climate action are presented below.

ISO 50001

ISO 50001 was developed to help companies take a systematic approach to continuous improvement in energy performance. This includes in particular the points of creating transparency in energy consumption, identifying potential savings and reducing energy costs. The approach is based on the concept of a continuous, iterative management method according to the proven PDCA cycle (plan, do, check and act) and is basically also applicable to municipalities. The main requirements of ISO 50001 include a clear definition of areas of tasks, scope and responsibilities, the implementation of systematic energy planning, the introduction and implementation of optimization measures and their systematic and continuous review and adjustment [24].

Local authorities can obtain certification for the implementation of energy management in conformity with the standard. The certificate is issued by an independent accreditation body that operates in accordance with international standards. These include, for example, Bureau Veritas, Dekra or TÜV. In the first phase of the external audit, compliance with the documentary obligations is checked. In phase 2 the practical implementation is inspected. This usually takes place in one third of the municipal properties with significant energy consumption, which are selected at random. After certification of the energy management system, the certificate is valid for three years. Until the next recertification, annual monitoring audits must be carried out to ensure continuous improvement of the energy management system.

European Energy Award

The European Energy Award (EEA) is a standardized management and quality assurance instrument for municipal energy and climate protection policy developed from the Energy City label established in Switzerland. Similar to ISO 50001, the implementation of the EEA at the municipal level also follows a continuous optimization process based on the "plan, do, check, act"-principle. With its catalogue of measures and implementation tools, the EEA is specially tailored to the needs of local authorities that implement national and global climate protection targets on site [25].

The participating municipalities are provided with a catalogue of measures, consisting of up to 79 measures in six areas of action, which can be actively influenced by the municipality. The catalogue of measures follows a holistic approach and addresses the topics of development and spatial planning, municipal buildings and facilities, supply and disposal, mobility, internal organization as well as communication and cooperation [26]. The first step is to form an interdisciplinary energy team consisting of local politicians, administrators, citizens and local stakeholders. The energy team is responsible for the implementation of the EEA, controls the processes in the municipality, collects data and is responsible for public relations and internal communication.

Performance and success of the municipalities are regularly reviewed by external auditors. An important part of the audit is the certification of the participating communities for their achievements in local climate protection. If at least 50 % of the possible points are achieved, the municipality receives an award. Municipalities with outstanding commitment and exemplary function, which achieve at least 75 % of the points, receive a gold award.

EMAS

The European EMAS-system (Eco-Management and Audit Scheme) is a quality assurance instrument in the field of environmental management in companies and institutions. The requirements of the international environmental management standard ISO 14001 are an integral part of an environmental management system according to EMAS, which also focuses on measurable improvements, internal and external transparency and legal certainty. The introduction of EMAS is intended to continuously improve environmental performance by increasing energy or material efficiency and reducing emissions, effluents or waste. EMAS thus goes beyond the goals of pure energy management, but the requirements for energy management according to ISO 50001 are almost identical to the EMAS system [27].

EMAS certification is carried out by an independent, accredited environmental auditor who verifies compliance with the EMAS-requirements for environmental management (on a site-by-site basis) and validates the organization's environmental statement with regard to validity and certainty. After a positive decision, the organization can be registered in the national EMAS-register and is thus entitled to use the EMAS-logo.

Other certifications

Within the framework of the German tool "kom.EMS", external quality assurance is offered on the basis of objective evaluation criteria and subsequent certification. The award is made in three quality levels – basic, standard and premium. For the quality levels basic and standard, so-called mandatory requirements must be implemented in 30 % respectively 60 % of municipal properties. The premium quality level can only be achieved through recertification. In addition to mandatory requirements, various additional requirements must also be met in 60 % of the properties. For quality assurance, there is a practical catalogue of questions, proof and evaluation, arranged according to fields of action [3].

Local German authorities which systematically reduce their energy consumption can also be certified by the German Energy Agency (dena) as energy efficiency municipalities. A prerequisite for the dena-certification is the fulfilment of 28 implementation criteria, which are compiled in a checklist. The certified local authorities receive a certificate, a sign to mount on a representative municipal building and a logo for use in publications, post mail or for their own website [18].

3 Case studies

As described in the previous chapter 2, the field of municipal energy management is very extensive and diverse. Just as diverse are the challenges and obstacles that municipalities have to overcome when introducing and establishing municipal energy management. While in small municipalities the challenges are often found in limited resources (financial and personnel), in large municipalities the creation of functioning structures and the coordination and communication of municipal energy management are of particular importance.

In order to gain a better understanding of the challenges and opportunities in the respective municipalities, three case studies from Germany are presented below and the special features of municipal energy management are discussed.

When selecting the sample municipalities, care was taken to ensure that a large city (> 100,000 inhabitants), a medium-sized city (> 50,000 inhabitants) and a small town were represented. In addition, it was emphasized that the municipalities pursue different approaches in the implementation and execution of municipal energy management, including an individual solution, the "kom.EMS management tool" and an external service. It was also taken into account that the municipalities can contribute suitable best-practice examples from the areas of setting up internal structures, executing energy controlling, implementing savings measures as well as approaches for consistency, quality assurance and exchange of experiences.

3.1 Large City – City of Stuttgart

The state capital Stuttgart is located in the middle of the federal state of Baden-Württemberg. It forms the center of one of the largest metropolitan areas in Germany. In December 2019, the population of the city was around 635,000, with a further 2.1 million people living in the immediate urban hinterland of the state capital. The population density is 2859 inhabitants per square kilometer [28].

Table 2:
Fact sheet for the case study Stuttgart.

Category	Large city
Residents	635,000
Municipal area	207 km² [28]
Gross domestic product	€ 53.1 billion [29]
Area of municipal properties	2.3 million m² [30]
Annual energy costs	€ 57 million [29]

The city of Stuttgart extends over a total area of 20,735 hectares. Almost half of this area is used for forestry and agriculture, about 40 % of it is located in nature and landscape conservation areas. The topography of the urban area is characterized by a basin in which the city center of Stuttgart is located, which is surrounded by a ring of hills [28].

With its numerous large companies, Stuttgart is the economic engine of the entire region and is considered one of the strongest and most innovative high-tech locations in Europe. The gross value added of Stuttgart's commercial enterprises amounts to over 57 billion euros per year, of which around a third is generated in the manufacturing sector.

The state capital Stuttgart has been a pioneer in municipal climate protection for many years. As early as 1997, a municipal climate protection concept with a comprehensive catalogue of measures to reduce greenhouse gas emissions was drawn up for the city as a whole. The climate protection concept was updated in 2007 with a time horizon to 2020. In 2018, a masterplan for 100 % climate protection was adopted by the local council, which sets out a strategy for decarbonizing the city as a whole by 2050 [31].

Stuttgart is also one of the pioneers in the field of municipal energy management. Since 1973, the CO_2-emissions of municipal properties have been recorded and documented for all types of energy. In 1977, the current municipal energy management was founded [32]. Due to its pioneering role, the City of Stuttgart has developed its own approaches to municipal energy management, most of which are described as best practice in guidelines and recommendations for action. The energy controlling software used in Stuttgart is also an in-house development, that has since been adopted by numerous municipalities.

The municipal properties currently cover a net floor area of 2.3 million m², of which 940,000 m² are in schools, 306,000 m² in hospitals and 143,000 m² in offices [30]. With an annual electricity consumption of 207 GWh and an annual heating energy consumption of 290 GWh, the energy costs amount to 57 million euros per year [32]. The municipal properties account for 4 % of the total energy consumption in the city area [31].

As a result of continuous municipal energy management and the consistent implementation of climate protection measures, greenhouse gas emissions from municipal properties were reduced by two thirds compared to 1990. This success is due in particular to the annual investments in thermal insulation, efficient building technology and renewable energies of currently around 4 million euros, which have more than halved heating energy consumption and reduced electricity consumption by 20 %. Since the changeover to green electricity in the years 2008 to 2011, the state capital's electricity consumption has been climate-neutral [32].

The highlight projects in Stuttgart include:

- Plus energy retrofitting of a school building
- Lucrative energy saving at Stuttgart schools “LESS”
- Self-financing instrument (“Intracting”)

3.2 Medium-sized city – Schwäbisch Hall

The district town of Schwäbisch Hall is located in the north-east of the federal state of Baden-Württemberg in the area “Hohenlohe”, 37 km east of Heilbronn and 60 km northeast of Stuttgart. It counts 40,755 inhabitants and the population density is 388 inhabitants per square kilometer [33].

Schwäbisch Hall is situated at an old salt spring in the deeply incised valley of the river Kocher (Kochertal). The newer districts and incorporated villages are mostly located on both sides of the river on the Haller Plateau (Haller Ebene), which is surrounded by the greater heights of the Swabian-Franconian Forest (Schwäbisch-Fränkischer Wald).

The total area of Schwäbisch Hall is approximately 10,500 hectares. Almost 80 % of this area is covered by vegetation, around 14 % are used for settlement and almost 8 % are traffic areas. [33].

Table 3:
Fact sheet for the case study Schwäbisch Hall.

Category	Medium city
Residents	40,755 [33]
Municipal area	104 km² [33]
Gross domestic product	€ 7.9 billion (incl. hinterland) [29]
Area of municipal properties	150,000 m² [34]
Annual energy costs	€ 3.3 million [34]

A mix of industry, medium-sized businesses, smaller companies, services and trade and the geographical location contributes to the economic attractiveness of Schwäbisch Hall.

Since 2009 an energy officer is responsible for energy management in the city administration. Schwäbisch Hall is using the tool "Kom.EMS" for energy management. Schwäbisch Hall was also chosen by the regional energy agency KEA as a municipality with model character for their engagement and they also won the golden European Energy Award which is awarded by the EEA in February 2020 for their efforts in energy management.

In addition to energy management, urban climate protection plays a central role in maintaining Schwäbisch Hall as a city worth living in for future generations. With its climate protection campaign "for a good climate", the city administration is committed to a good climate and serves as an information platform for climate protection and energy saving projects for citizens in Schwäbisch Hall and supports them in their own climate protection projects [35].

The highlight projects in Schwäbisch Hall include:

- Conversion of street lighting to energy-efficient LED lighting by 100 %.
- Thermal insulation, retrofitting of heating system and installation of a photovoltaic system in the primary school Kreuzäcker
- European Energy Award in gold in February 2020.

3.3 Small town – Teningen

The community of Teningen, which was created as a result of merging several small municipalities has 12,127 inhabitants. The community of Teningen consists of the districts of Teningen, Köndringen, Landeck, Nimburg, Bottingen and Heimbach. The size of the district is 4027 hectares, including 1472 hectares of forest area, 622 hectares of settlement area and 1760 hectares of agricultural area [36].

Table 4:
Fact sheet for the case study Teningen.

Category	Small town
Residents	12,127 [36]
Municipal area	40 km² [36]
Gross domestic product	not known
Area of municipal properties	52,500 m² [37]
Annual energy costs	€ 700,000 [37]

Geographically, the municipal area of Teningen is crossed by the three rivers Elz, Glotter and Dreisam. It is also located near to the federal highways 5 and the Rhine Valley rail, which are important for transportation in southwestern Germany.

Due to good connection to the long-distance traffic, Teningen has developed from an exclusively agricultural community to a modern industrial and residential community and has become one of the largest industrial communities in the Emmendingen district. Because of its large commercial and industrial sector, Teningen is indicated as an industrial region in the regional plan. Together there are around 800 trading, craft and commercial businesses with around 4500 jobs.

In 1999 an energy management system was implemented based on a management tool of the local energy supplier. Since then all relevant energy parameters of the municipal properties have been managed and improved continuously together with the energy supplier. The energy consumption of Teningen has been 1.6 GWh and the heat consumption of the properties reached 6.2 GWh in 2018 [37].

The community of Teningen is aware of its role model function and its responsibility for citizens as well as for future generations and thus for the environment.

It recognizes environmental protection as a central municipal task. A high level of commitment to environmental protection should ensure that environmental considerations are adequately taken into account in all decisions that affect our living space. Local environmental policy will thus contribute to the sustainable development of the community. This obligation includes the local government, local self-owned companies and the political organs.

The municipal council in 1999 decided to have the central administration, including the municipal administrative units and areas, evaluated and certified [36]. The good results that the evaluation and certification achieved concerning ecology and economy led to revalidation in 2009. With ten years of uninterrupted EMAS-certification, the community of Teningen is celebrating a small anniversary that not many communities in Germany can show.

The highlight projects in Teningen include:

- Educational program on agriculture and climate protection
- Conversion of the power supply to 100% green electricity
- Founding of an energy cooperative for the operation of PV systems on municipal roofs

4 Spot lights on best practice

In the following chapter, individual aspects of municipal energy management in the three sample municipalities are examined. The results presented are based on a survey of the three municipalities. An interview guideline was developed for the survey, which includes a total of 35 questions on the topics of internal organization and structure, data collection and data evaluation, energy optimization, and consistency and networking.

The interviews were conducted on a telephone basis, with the interview questions being made available to the interviewees in advance and the transcribed interviews subsequently agreed with the interviewees in terms of content. The questionnaire used and the answers of the interviewed municipalities can be found in the appendix.

4.1 Internal organization and structure

4.1.1 Tasks and responsibilities of municipal energy management

Stuttgart, the capital of Baden-Württemberg, has developed plenty of tasks and responsibilities in more than 40 years, starting with the central handling of energy issues from the design of buildings, through planning and operation to demolition or sale. The tasks of the current municipal energy management in Stuttgart include:

- Monitoring services of energy and water consumption
- Allocation of energy costs
- Energy procurement including controlling of energy supply (central fuel procurement, tendering of on-grid energies like electricity and gas)
- Central database with the complete energy consumption and costs of municipal properties

- Energy billing and documentation of the system data and renewable energy systems (basis for the preparation of energy certificates)

- Advices for caretakers and technical services on energy-efficient operation of technical systems, error analysis, initiating measurements, adjusting control parameters of building automation in consultation

- Weak-point analysis and proposals for measures to save energy and water (e. g. plant renewal, PV-systems), also preparation of energy audits

- Creation of district concepts, energy management planning for new building projects in the urban area

- Monitoring of renovation and new construction projects

- Development of guidelines for the energy and water sector in coordination with the technical offices

- Acquisition of financial resources: applications for subsidies from the federal and state governments, as well as internal contracting

- Research and demonstration projects: Implementing research projects nationally and internationally with project partners from the research community and inner-city specialist planners

- Public relations: preparation of annual energy reports, CO_2-balances, project information and press articles

- Projects to change user behavior

Other issues of the municipal energy management team are:

- Research and demonstration projects: Implementing research projects nationally and internationally with project partners from the research community and inner-city specialist planners

- Technical support for the municipal energy saving program for citizens

- Energy concept for the entire city with the goal of a climate-neutral energy supply in 2050

Compared to Stuttgart, Schwäbisch Hall is a newcomer in the field of energy management. They started just 11 years ago, and since then have focused on controlling and optimization of energy and the support of the department of planning and construction for refurbishment and new construction plans.

Similar, although they have been taking actions for almost 30 years, Teningen is also focusing on energy monitoring and controlling, the water consumption, the creation of planning bases for renovation and new construction, but also dealing with waste management and cleaning.

4.1.2 The administrative anchoring

The city of Stuttgart has implemented energy standards that are binding in the Energy Directive [38]. The Energy Management in the Office for Environmental Protection acts as a control body and provides advice in cases of doubt. The offices are the operators of the houses including the technical installations; in many cases, the Building Construction Office acts as planner.

Schwäbisch Hall instead has installed the Energy Officers as a staff unit at the Lord Mayor's office and thus advises across all offices.

Teningen on the other hand has concentrated all tasks and responsibilities around the topic Energy in a Department that is taking care of planning, construction and environment. Property management is also carried out entirely by this department, so responsibilities are clearly defined and no interdepartmental organization is required.

4.1.3 Internal communication and reporting

Similar to the previous points, the internal communication and reporting in Stuttgart is the most sophisticated one. A communication campaign for general public is in progress. In the city council, the adoption of the action package "World Climate in Need" has bindingly defined the distribution of tasks and responsibilities within the city administration. A staff unit for climate protection monitors the achieved goals; there is an annual information and reporting obligation.

Schwäbisch Hall is publishing its energy report on their website, they have accepted the climate protection concept of the EEA, which holds detailed measures. But overall there is the prominent statement of their Lord Mayor "in four years we will get the gold award of the EEA again".

Teningen is preparing annual energy reports, which are internally coordinated with the responsible caretakers. In the EMAS-report, the findings of municipal energy management are published.

4.1.4 Staff capacity

As shown above under 2.3 in this report, the capacities for the energy management system varies with the number of the inhabitants of the municipalities and the area of the municipal properties. Concerning these numbers Stuttgart should have 10 employees. At the moment 11 people are working there, due to the numerous tasks that are listed above, which also include tasks for the municipal environment management (see chapter 4.1.1), this seems absolutely justified. Taking a look at the numbers of Schwäbisch Hall, they are supposed to have one employee. This is actually the case, if we take into account that the other employee is taking care of the municipal environment management. In Teningen (with less than 50,000 inhabitants), the tasks of municipal energy management are divided among three employees who, in addition to their other tasks, take care of municipal energy management on a part-time basis.

4.2 Data acquisition and evaluation

4.2.1 Consumption monitoring

Annual consumption data is recorded and evaluated for all 1400 properties and buildings in Stuttgart. 220 of these properties with a particularly high energy consumption are managed by the in-house energy service. The energy service has the task of continuously monitoring the energy consumption in these properties and reducing energy expenditure through targeted operational optimization. The properties managed are mainly schools, swimming pools, hospitals, operational buildings, administrative buildings, sports facilities and cultural buildings [32]. These properties account for 64 % of the city's energy costs and cover more than half of the net floor area to be heated. There are 85 properties under closer monitoring, where consumption data is collected and evaluated daily via remote data transmission. If required, the measured values can also be recorded at 15-minute intervals. In the remaining properties that are not under intensive monitoring, the consumption values are recorded manually on site at weekly, fortnightly or monthly intervals and transferred manually to the central energy management system. The number of remotely monitored systems is being successively expanded, taking into account the costs and benefits.

In Schwäbisch Hall, a total area of around 130,000 m² net floor area is monitored by the energy management system. The properties monitored include schools, sports buildings, cultural facilities, company buildings, childcare facilities and administrative buildings. Not included in the municipal energy management is a swimming pool, which is managed by the energy utility, as well as the municipal own businesses (cemetery and sewage disposal), that carry out energy management on their own. The consumption values of large consumption points are recorded manually at least monthly, and in some cases daily by the responsible caretakers on site. In addition, load profile meters for remote readout are installed in five properties. At smaller consumption points, consumption data is recorded manually in an annual cycle. The recorded energy consumption data is regularly transmitted to the energy management system, where it is evaluated. If required, temperature measurements are carried out in conspicuous properties using mobile measuring technology [35].

The municipality of Teningen records the energy consumption of all municipal properties manually based on the annual energy bills. Exceptions to this are the energy consumption of individual stoves and household electricity in rented residential buildings (data protection). The available consumption data are transmitted via cloud-based software to an external service provider, who prepares an energy report based on the annual consumption data. The results of the energy report are reviewed by the energy management team together with the responsible caretakers and are used to derive optimization measures for system operation.

4.2.2 Data analysis

The evaluation of the energy data in Stuttgart and Schwäbisch Hall is carried out independently with the aid of energy controlling software. Due to limited personnel resources, the municipality of Teningen has outsourced the data evaluation to the local energy supplier.

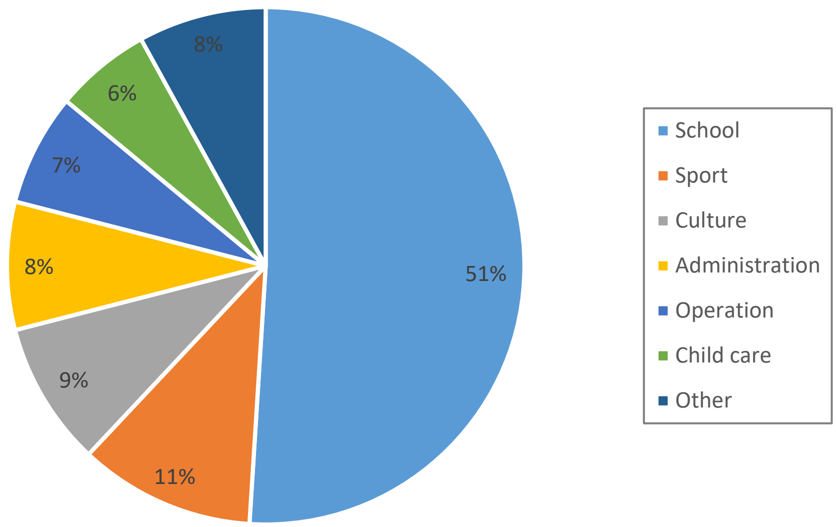

Figure 3:
Distribution of thermal energy consumption in Schwäbisch Hall [34].

The results of the data evaluation vary greatly depending on the issue and data availability. Figure 3 shows a pie chart presenting the shares of different types of buildings in heating energy consumption in Schwäbisch Hall. It can be seen that school buildings account for more than half of the heating energy consumption (51 %), followed by sports buildings and cultural facilities. Depending on the issue at hand, a breakdown by building age, energy source, organizational unit or building size can also be made.

With an evaluation of the energy data by category, special features in the clusters formed can be worked out. For example, area-specific characteristic values for energy consumption, CO_2-emissions or energy costs can be derived for individual clusters, which can be used as reference values for benchmark analyses. Figure 4 shows the area-specific energy costs for different types of use in Schwäbisch Hall. It can be seen, that sports buildings have comparatively low energy costs, while buildings used for cultural purposes have significantly higher energy costs. Such an evaluation can also be very helpful for prioritizing properties for renovation measures. For example, clusters that have a particularly high energy consumption or have a high proportion of floor area are of greater importance and should be examined in detail with regard to possible savings potential.

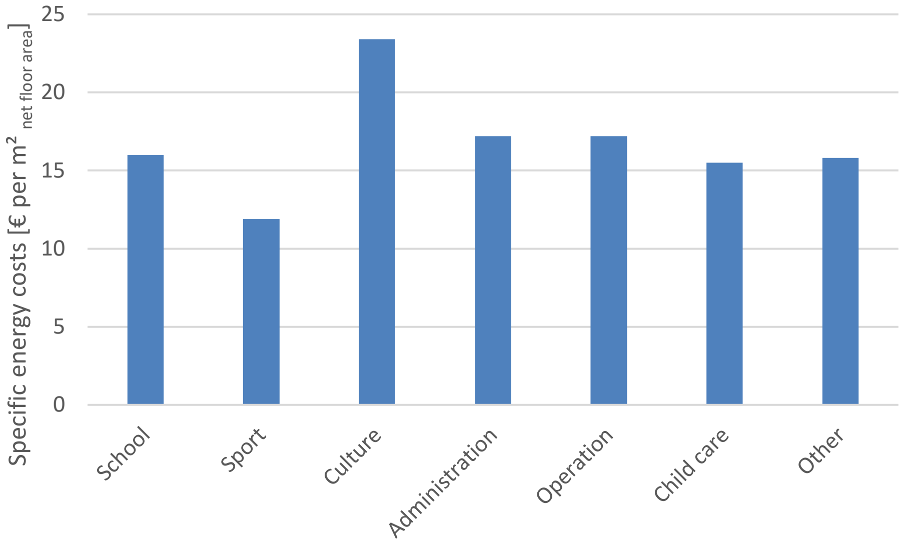

Figure 4:
Specific energy costs of different buildings in Schwäbisch Hall [34].

An analysis of the time course of energy consumption can provide information on whether the goals of municipal energy management are being achieved. Whereas in Stuttgart, for reasons of clarity, the temporal developments for heating, electricity and water are shown in separate tables, in the energy report of the municipality of Teningen, all three consumption variables are presented together in one diagram (see Figure 5). The red columns represent heating energy consumption and the yellow columns electricity consumption. On the right-hand scale, water consumption is shown with a blue line. The graph shows that in 2017 there was a significant increase in water consumption, which was exceeded again in 2018. Heating energy consumption also shows a significant increase between 2017 and 2018, while electricity consumption has remained almost constant. Once these particular curves have been detected, further investigations can be carried out to identify the cause of these increases.

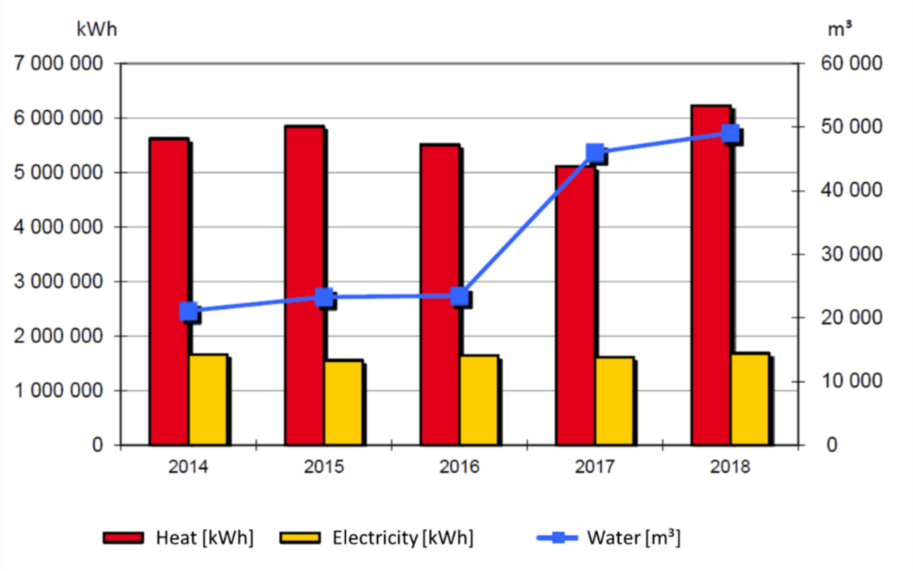

Figure 5:
Time course of the energy consumption of municipal properties in Teningen [37].

The Teningen energy report also includes a benchmark analysis. For the benchmarking, the properties are categorized according to their use and consumption figures are derived. The arithmetic mean of all properties monitored by the energy supplier in the respective category is determined as the reference value. The reference value is thus dynamic and reflects the development of municipal climate protection in the participating municipalities.

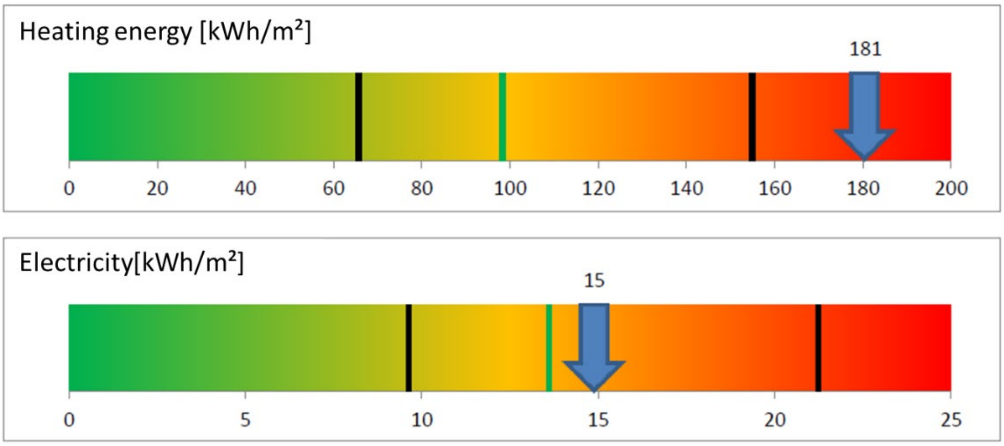

Figure 6:
Consumption parameters and benchmark analysis for a kindergarten in Teningen [37].

Figure 6 shows the benchmark analysis for a kindergarten in Teningen. The consumption values of the property are marked with thick blue arrows on a so-called band tachometer. The two black bars mark the area within which the consumption values of comparable properties are usually located. The green bar represents the target value that should be achieved by savings measures.

In the concrete example, the kindergarten shows an increased consumption value for heating, which is outside the usual range. The reference value of 100 kWh/m² is clearly exceeded, which indicates a considerable savings potential. For electricity consumption, on the other hand, the consumption value is very close to the reference value of kindergarten buildings. It can therefore be assumed that there is not much potential for savings in electricity consumption [37].

4.2.3 Energy controlling software

For municipal energy controlling in Stuttgart, the in-house development "Stuttgarter Energiekontrollsystem" (SEKS) is used, which has proven itself over many years and is now also used in various other municipalities such as Schwäbisch Hall.

Figure 7:
Energy controlling software "Stuttgarter Energiekontrollsystem" (SEKS) [39].

With this energy controlling software, the energy consumption of the municipal properties can be aggregated and put in relation to weather conditions and the net floor area of the building. In this way, comparability between different years and buildings can be achieved. In addition to this central function, SEKS also offers the possibility of creating energy consumption certificates and interfaces to planning tools and standard programs for electronic data processing. The SEKS software consists of different functional areas (see Figure 7) [39].

In the "Administration Area", users can be registered, user accounts can be managed and the most important system parameters can be adjusted centrally. In addition, there is a communication platform in this area for direct exchange between users.

In the area "Basic Data", individual settings of program parameters (type of result output, color display, etc.) can be made and daily average temperatures can be entered for the calculation of degree day figures. In addition, the master data of the energy management such as energy sources, meter types, times of use, organizational units, street index and building types are maintained there.

The module "Building Management" is used to manage the monitored objects in energy management. Here, object data (building name, reference area, building type, responsible organizational unit, etc.), building data (year of construction, building shape, U-values, component areas and volumes), energy prices, energy key figures and meter definitions can be made and the existing heating technology documented. A document archive is available for assigning building-specific images and external files.

In the program section "Own Meter Readings" the input of meter readings and consumptions takes place. Data entry can be done manually, by importing consumption lists (e. g. MS Excel) or automatically in quarter-hourly values by means of remote data transmission. A plausibility check of the data is carried out regardless of the type of data transfer. The results can be called up immediately after the input confirmation.

Consumption data for grid-bound energy sources (gas, electricity, district heating) are read in via the module "Energy Utility Data". Flexible options are available for importing bills, partial payments and cancellations. Automatic transmission of meter readings via remote data transmission is also possible. Appropriate interfaces are provided for data transfer to common financial systems for automatic posting of expenses.

In the program section "Energy Procurement" the user is supported in defining lots and obtaining offers. For this purpose, an automated determination of consumption from delivery and remaining quantities, a monetary valuation of remaining quantities and a function for accounting surplus quantities can be used. Order forms are available for tendering, which can be adapted by the user.

The input data is processed in the central module "Energy Service", from which the module "Energy monitoring" is controlled. In the module "Annual Accounts" the consumption statistics and energy balance are prepared, from which the information for the preparation of the energy report is drawn.

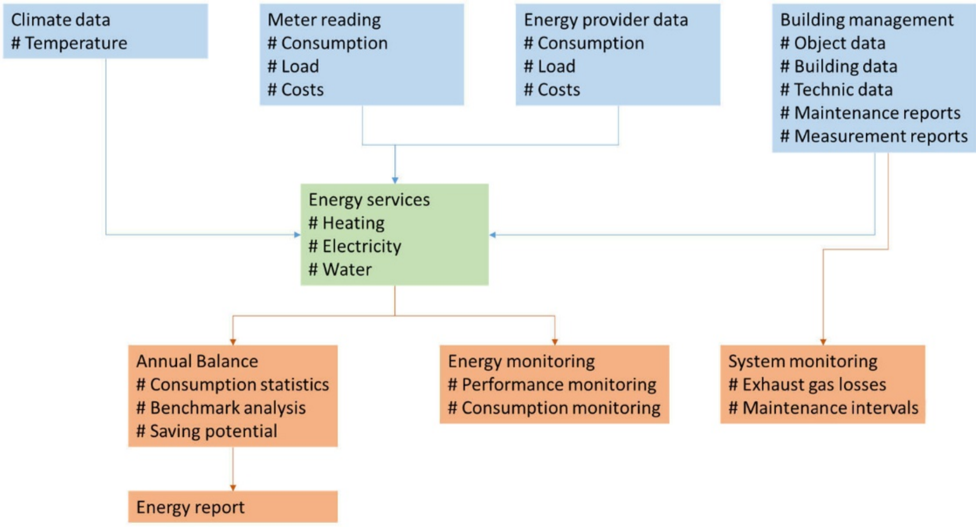

Figure 8:
Operating principle of the SEKS software [39].

4.3 Energy Optimization

4.3.1 The operating environment of energy management

Basically the operating environment for energy managers is similar, but of course differs due to the different sizes of the municipalities. In Stuttgart on the basis of the energy controlling results and after an intensive analysis, the Office for Environmental Protection recommends retrofit measures. The responsible institution (e. g. the office that manages the building) usually contributes to these measures. In Schwäbisch Hall, when prioritizing retrofit measures in the context of budget planning, this data is taken into account in the decision-making process. In Teningen an investment decision is usually based much more on maintenance requirements, development planning or new legal framework conditions, not on the findings of energy management. But they can provide the impetus for renovation.

Usually the energy manager (energy team) is involved in the decision-making processes for the concept, planning and implementation of energy optimization measures. While Stuttgart has its regulation by the Energy Directive, Schwäbisch Hall is using the above mentioned budget planning to give their vote. At Teningen the findings of energy management serve as a planning basis for large properties; energy management is involved as an advisor.

4.3.2 Financing

Usually the municipalities, and this is the case with Schwäbisch Hall and Teningen, have funds, that are available as part of general building and civil engineering maintenance. The energy saving measures are financed within the framework of this budget, no further.

In Stuttgart, if measures cannot be implemented with the respective budget, the Energy Economics Department supports municipal offices and utilities with the city's internal contracting, which the city of Stuttgart introduced in 1995 (see Figure 9) and by acquiring state and federal subsidies.

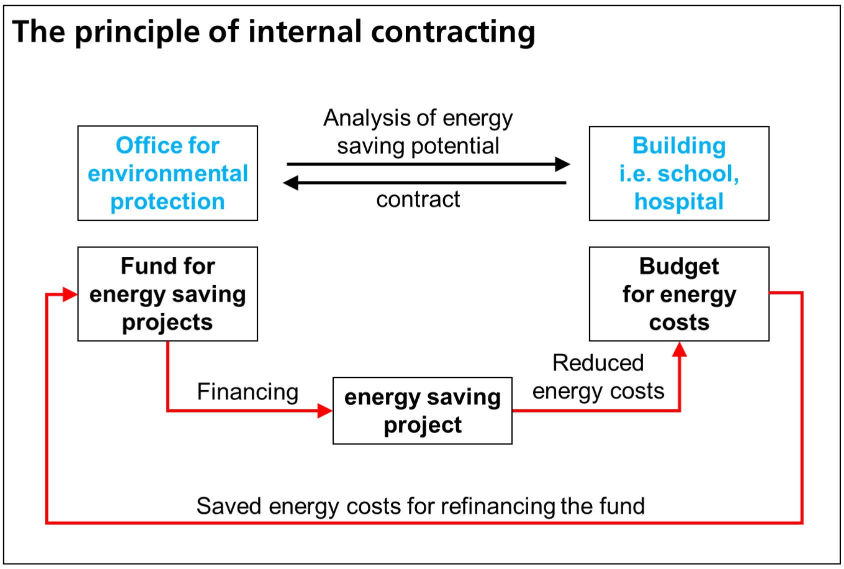

Figure 9:
Principal of in-house contracting in Stuttgart [40].

Stuttgart's Internal Contracting links different independent parts of the city authority to enable quick and flexible investment decisions. Its operational scope is energy improvements within the municipal building stock. The scheme is exclusively operated as an internal process wherein the underlying revolving fund functions as an intermediate buffer for cash flows. The fund is embedded within Stuttgart's regular accounting system as a part of the city's general budget. Every financing aspect (investment, (saved) energy costs, payback) remains under the municipality's control [41].

By the year 2015, more than 350 agreements have already been concluded between Stuttgart's Office for Environmental Protection and the municipal offices and utilities concerned. Since 1995, more than 22 million euros have been saved through in-house contracting. The net profit in 2015 was 1.2 million euros [32]. The financial resources provided (black line) and the energy savings achieved (red line) are shown cumulatively in Figure 10. The graph shows that initially the focus of the savings measures was on heating energy. From 2008 onwards, electricity saving measures were also increasingly financed by the city's internal contracting.

In addition with its internal contracting, the Office for Environmental Protection has a special budget that can be used outside the budget consultations for renovation measures to save energy and to promote renewable energies.

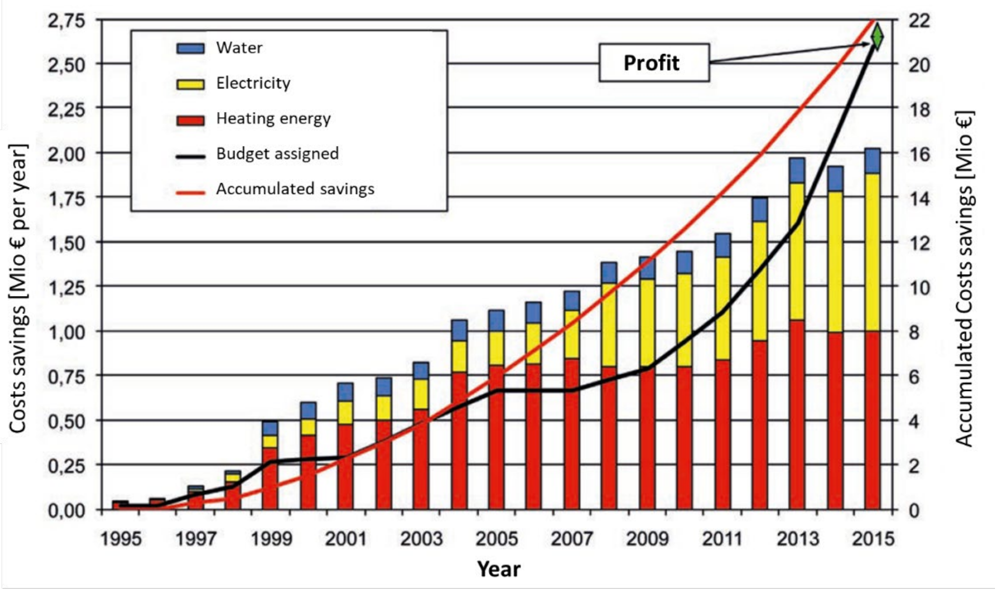

Figure 10:
Costs savings through in-house contracting in Stuttgart [32].

4.3.3 Energy savings

Part of any energy management system is to deal with energy consumption. Rising energy prices also mean rising energy costs. Through continuous monitoring of energy within the framework of an energy management system, weak points in energy use can always be identified and remedied through appropriate measures. This ensures an increase in energy efficiency, which in turn means that energy costs can be kept permanently at a comparatively low level.

A great success of the municipal energy management in Stuttgart is the reduction of the heating energy consumption by 50 % since the beginning of the energy management in 1977. This corresponds to the annual heating energy requirement of 20,000 four-person households. Compared to 1990, over 23.8 % less heating energy was used in 2015. However, electricity consumption rose by 28.7 % over the same period. Taking into account the 100 % purchase of renewable electricity by the city administration, CO_2-emissions are reduced by 65.7 %. The citywide target of -20 % CO_2 has already been achieved for the urban properties. In 2015, the number of plants in the field of renewable energies increased by 9 to 83. The area of the photovoltaic systems increased by 5 % and cogeneration was expanded. These increases in energy efficiency lead to annual CO_2-savings of 28,494 t CO_2 per year and a reduction in primary energy requirements by 21.7 % since 1990. The regenerative share of heating energy is 8.3 % and for electricity 6.7 % of the total energy consumption. Since the start of energy management in 1976, the total energy and water savings in the urban properties have increased to over 652 million euros. This illustrates the economic and ecological benefits of the implemented measures and energy management in the capital of Baden-Württemberg [32].

In Schwäbisch Hall savings from 2009 – 2018 were about 10 million euros respectively 34 GWh. 24.5 GWh were saved for heating and 5 GWh for energy consumption [42]. The measures taken concerning the optimization of the public buildings has led to these results in less than a decade. With the new LED street lighting 0.8 GWh per year could be saved [43]. To inform citizens, every two years a report is published on the website, which allows to get detailed information on the energy consumption of the properties.

For Teningen savings are documented in the EMAS-report [36]. Through the introduction of municipal energy management, savings of more than 20 % could be achieved in the first five years through non-investment and low investment measures. For example in 2019 the consumption of thermal energy in the municipal buildings and facilities fell to 51 GWh and, at 16 GWh, was at the average level of the previous years for light and power electricity. Through great efforts during the last years the CO_2 could be kept constant around 1000 tons. It is already one of the successes of an energy management system, to keep the consumption levels from growing.

4.3.4 User awareness

Schwäbisch Hall takes part in the "Fifty/Fifty" energy and money saving program, which is offered as an incentive system to all schools. 12 of 17 schools are taking action, which is a good quote. The schools get support, if necessary. The billing is not exclusively related to savings in order to give small schools a higher incentive (400 euros basic remuneration + 150 euros per campaign (max. three campaigns per year) and 20 % of the savings) [35]. The program has proven itself and will be continued and kept attractive by new elements. In addition, there is the possibility of an extension to administrative buildings and activities tailored to day-care centers are also conceivable. The program is supported by the state of Baden-Württemberg and documented in a guideline available on the https://www.fifty-fifty.eu/downloads/.

In order to support schools in the responsible use of energy and water, the Office for Environmental Protection and the School Administration Office of Stuttgart offer the LESS program (Lucrative Energy Saving in Stuttgart's Schools). The aim of the project is to anchor the topics of energy saving, sustainability, resource and climate protection in schools.

All users of the schools, students, teachers and caretakers can help to save electricity, heating and water in the school buildings. As a reward, the schools receive up to 1000 euros of the saved energy costs for their own purposes. If the energy savings can be maintained in the following years, the amount is paid each school annually. If energy consumption rises again in the following period, payments are no longer made. In order to give the schools equal opportunities regardless of their size, the profit sharing is based on the percentage savings (see Table 5) [44].

Table 5:
Financial participation by schools in the energy savings achieved.

Savings [%]	Revenue [€]
0	0
1	250
4	500
7	750
10	1000

4.3.5 Optimization measures for public buildings

Building renovation

Schools are particularly important for the energy consumption of municipal properties. In Stuttgart, for example, schools account for over 30 % of heat consumption [31]. The refurbishment of the Stuttgart Uhlandschule into a plus-energy school thus represents a milestone in municipal climate protection. After the renovation, which lasted from 2009 to 2013, the Uhlandschule generates in an annual balance more energy than it consumes for heating, domestic hot water generation, ventilation, lighting and all other energy uses. This goal was achieved by means of a holistic upgrade of the building envelope and the building services. The thermal insulation of the exterior walls and the roof was made of 30 cm expanded polystyrene with an optimized thermal conductivity. On the gable side and for the insulation of the floor a vacuum insulation was used. With a U-value of 0.8 W/m²K, the new windows meet the requirements of passive houses, as does the construction of the roof and the exterior wall. With these insulation measures the heat loss could be reduced by 80 % compared to the unrenovated state.

The energy supply of the school is provided by a geothermal heat pump in combination with a low-temperature panel heating system. In summer, this panel system can also be used for conditioning without the need for active cooling. The ventilation concept provides a decentralized hybrid ventilation, i.e. natural ventilation in the summer months and a ventilation system with heat recovery that can be controlled room by room provides ventilation during the heating period. The school is lit by daylight and presence-controlled LED lights. As protection against overheating, an external sun protection system consisting of blinds was installed. To ensure an adequate supply of daylight, the blinds are equipped with a light-directing function in the upper third of the curtain. The electricity for the operation of the school and the surplus energy is generated by photovoltaic modules on the roof surfaces and in the parapet area of the south façade directly on the building. The total area of the PV-system is 1800 m² with a total output of 220 kW_p [45].

Figure 11:
Photovoltaic modules on the parapet area of the south-facing facade of the Uhland School in Stuttgart.

Also in 2009, the building envelope of the Kreuzäcker primary school in Schwäbisch Hall was thermally insulated as part of the German government's economic stimulus package. This was followed in 2012 by the installation of a gas condensing boiler to replace the heating system. Figure 12 shows that the specific heat consumption of 200 kWh/m²yr in 2008 was reduced below 85 kWh/m²yr by the insulation measures. After replacing the heating system, the energy consumption is < 70 kWh/m²yr, which is one third of the initial value [42].

The photovoltaic system installed on the roof of Kreuzäcker primary school generates 57.5 MWh of electricity over the year. Subtracting the electricity consumed by the school itself, this results in an electricity surplus of 36 MWh, which is fed into the public grid. On the electricity side, the school is therefore a plus-energy building, but the renewable electricity is not quite sufficient to compensate for the emissions caused by heating the building. To become completely climate-neutral, for example, the heat supply would have to be converted to heat pumps [42].

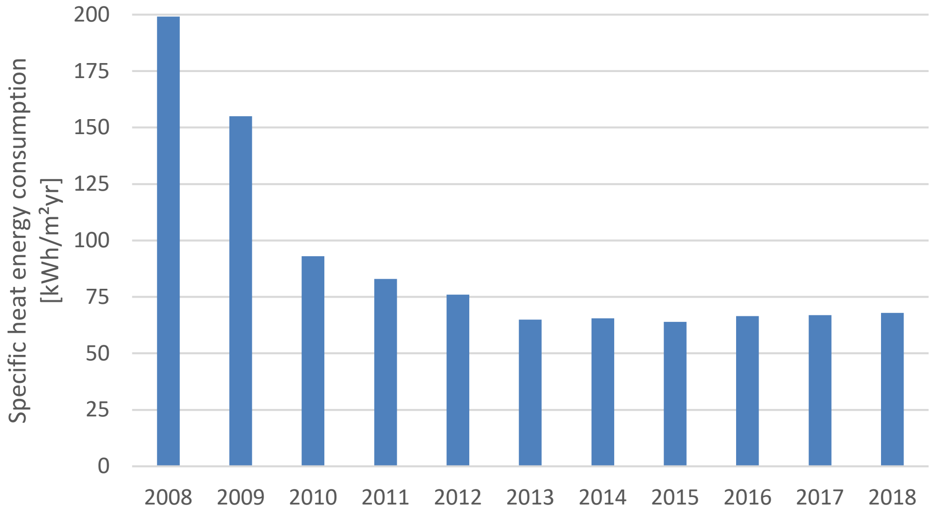

Figure 12:
Development of heat consumption of the Kreuzäcker primary school in Schwäbisch Hall [42].

LED lighting retrofitting

Investigations in the area of the lighting system of properties in Stuttgart in 2014 have shown that in order to reduce the power supply approx. 230 linear luminaires could be converted to LED tubes (retrofit system). With this system only the illuminants (fluorescent lamp) are exchanged for LED tubes, as the old luminaires are still equipped with conventional ballasts.

Before the conversion, a sampling was carried out with the involvement of the users with positive result. The conversion of the luminaires to LED light sources was carried out by the technical staff. The necessary investment costs of 10,000 euros were also covered by the city's internal contracting. By converting to LED lighting, the electricity consumption could be reduced by about 30 MWh annually. This corresponds to a cost saving of 4000 euros per year and a CO_2-saving of 17 tons CO_2 per year. The capital payback period is less than three years. The differences between the different lighting types are hardly noticeable [32].

Operation optimization

Two school buildings and a retirement home from Stuttgart are good examples of the savings potential that can be achieved by optimizing the operation of the building services.

The school building of the Martin Luther School dates from 1902 and was completely renovated in 2000 and 2007. After the renovation, the annual heat consumption was 64 kWh/m²yr, which was higher than the originally calculated consumption value. By adjusting the heating control during operation, the characteristic consumption value was reduced to 56 kWh/m²yr, thus achieving cost savings of 3600 euros per year. The main adjustment parameters that have contributed to consumption optimization are the setting of the heating curve, a limitation of the room target temperature at day and night time and a readjustment of the heating limit [32].

In the Rosenschule, a historical monument, almost 30 % of the heating energy consumption was saved by optimizing the operation of the heating system. Savings of 9000 euros in energy costs were achieved as a result. The optimization measures carried out include the seasonal shutdown of circulation pumps in the heating distribution network, a temperature-dependent shutdown of heating circuits, a reduction of the distribution temperature at night and holiday times and the conversion of the operation of the boilers from permanent parallel operation to partially parallel operation at peak load times [32].

The retirement and nursing home "Hans-Rehn-Stift" is supplied with heat by a combination of a combined heat and power unit, heat pump, gas boiler and thermal solar system. An analysis of the energy consumption data showed a significant increase for heating energy in 2014. A closer look also showed that the coverage share of the heat pump had decreased significantly, while the share of the CHP and gas boiler had increased. A defective time controller in the control cabinet of the heat pump was found to be the cause of the shift and was replaced. In addition, the flow temperature of the heat pump was also reduced in this step, which increased the annual performance factor of the heat pump from 3.0 to 3.3. The resulting cost savings amounted to 4300 euros per year [32].

The municipality of Schwäbisch Hall has chosen a special way for the energy optimization of the municipal library. Due to the structural and technical design, the building had extremely high energy consumption in both the heating and electricity sectors. In addition, the installed technology did not allow for a targeted control of the heating and cooling of the building. In order to leverage the existing savings potential, a contract was concluded with the local energy supplier for the implementation of energy saving measures with a savings guarantee. The implementation of the energy saving measures took place in summer 2010, the main performance phase of the savings contracting started in January 2011. Over a period of ten years, the external energy service provider will control and optimize the technical building equipment and guarantee savings of around 50 % for both the heat and electricity requirements of ventilation and cooling. The guaranteed cost reduction is 20,350 euros [46].

In order to be prepared for the supervision of the technical building equipment, the caretakers and technicians in Schwäbisch Hall are trained individually on the respective system. The energy manager deals intensively with new caretakers in particular. This approach has proven itself over a longer period of time and appears to be more suitable than a general training course, as it allows the special features of the building systems to be dealt within the best possible way.

In the municipality of Teningen, operational optimization is an essential part of the municipal environmental statement, in which the municipality commits itself to continuous improvement of the environmental situation in the municipal properties and to a reduction in resource consumption [36]. In the field of rational use of energy, the measures taken include the development of schedules, the training and motivation of technical staff to service, check and maintain the building services and the preparation of service instructions to support energy saving behavior and efficient system operation.

4.3.6 Optimization measures for public lighting

Whereas Stuttgart is successively replacing its street lighting to LED, Schwäbisch Hall has replaced its system almost completely in the last years.

Street lighting is a major consumer of electrical energy in municipal properties. Before the start of converting street lighting to energy-efficient LED lighting, almost half of Schwäbisch Hall´s total electricity consumption was generated by it. In 2013 the consumption amounted to 2680 MWh, which corresponds to the consumption of approximately 600 four-person households. This added up to energy costs of almost € 600,000.

By 2019, 6750 of about 7500 lights had been converted to modern LED lights. With the renovation, an innovative control software was installed, which allows to dim the lights as required. For example, they only are used at 50 % of the output power after midnight, which is still sufficient for safe lighting. The consumption compared to the previous lamps is reduced by up to 80 %, with the same or even higher basic brightness. Other advantages of LED lighting are the longevity of the luminaires, which reduces maintenance, insect friendliness and the reduction of unwanted scattered light effects (dark sky).

The success of the conversion is reflected in the bills of the energy supplier. Consumption and costs have been more than halved since 2013, despite several new development areas. With a capital return period of around seven to eight years, the measure is also economically viable. The various construction phases were funded by the state of Baden-Württemberg (program Klimaschutz-Plus) or by the federal government.

It is also worth mentioning, that Teningen is experimenting with a “Smart Street Lighting Solution”. They have changed 50 % of the old sodium vapor lamps to LED. In some cases, the street lighting was already installed with a demand-based control system (e. g. route to a remote railway station). There are five WLAN stations in total, and the “Smart Grid” solution is even used for traffic monitoring – the small municipality has understood the potential in this new infrastructure and is making its first own experiences, to prepare further steps for their future.

4.4 Consistency and Certification

Since Stuttgart has been taking energy management serious for more than 40 years, they have installed their own methods and tools to be implemented and to be kept consistently active (compare anchoring chapter 4.1.2).

The city of Schwäbisch Hall has been participating in the European Energy Award since 2014 and has already achieved gold status at the second audit. In the central field of sustainable energy generation, the municipal utilities (Stadtwerke) operate as a municipal subsidiary. In 2018, they reached the target of 100 % renewable energies originally issued for 2030 at power generation primarily through the consistent expansion of wind energy. The nationwide pioneering position in the expansion of the local heating network supports the city through continuous designation of priority areas for local heating networks both in new buildings and existing areas.

A second focus is on comprehensive energy management. Besides the energy-efficient renovation of buildings, the municipal vehicle fleet is gradually being converted to E-vehicles. This not only improves the city's CO_2-balance, but also reduces its own energy costs.

As a third pillar, the city's climate protection management has an impact on the population. With the claim "For a good climate", citizens are motivated to make their own contribution to climate protection. There are information campaigns, support programs and educational projects for schools and day-care centers.

Like quality management systems for businesses and the industry, the EEA is based on a process of continuous improvement. This not only ensures an increase in energy efficiency, but also the use of renewable energies and sustainable approaches to mobility.

However, in contrast to other quality management systems, the European Energy Award integrates two additional key factors for success:

1. Each municipality is assisted by an external EEA adviser providing technical and organizational support throughout the entire EEA process.

2. Certification under the European Energy Award or the European Energy Award Gold provides an incentive for other municipalities that are not yet certified, plus certified municipalities are able to use the award for location marketing purposes.

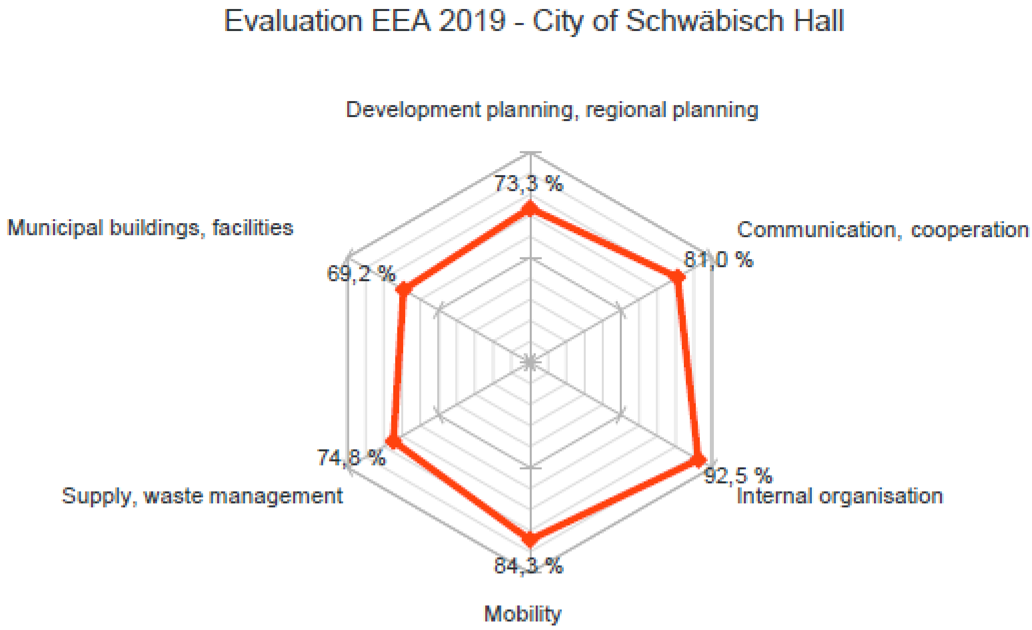

Figure 13:
Assessment of Strengths and Weaknesses, EEA evaluation for the City of Schwäbisch Hall in 2019 [47].

Figure 13 shows the profile of strengths and weaknesses of Schwäbisch Hall in 2019. Strengths are, for example, in the area of internal organization, where it has already reached 92.5 % of its potential. By implementing additional planned activities, it will be able to raise the awareness to take more actions regarding the optimization of Municipal buildings and facilities.

In comparison, Teningen is using the EMAS-certificate to keep the energy management system on a high level. It is a performance-based system that can be used for climate protection, sustainability and resource conservation.

Like the EEA, EMAS is also a continuous process and although a major step is accomplished after registration or renewal of registration, the process continues seamlessly into the management cycle. The environmental program must be updated, new ideas and suggestions for improvement developed, if necessary new environmental audits made, employees trained and internal audits carried out. In short: everything must be kept up to date and regularly documented to secure consistency with the certification guidelines.

4.5 Networking

Like many activities, the energy management system lives from exchange and inspiration. Many problems communities face are comparable or when compared help to clarify similarities and differences to better classify them. Therefore many networking organisations with different focal points have been founded from regional to international levels. The following will give an overview of the networks, organisations and working groups used by the interviewed municipalities.

Stuttgart and Schwäbisch Hall are partners of the German Association of Cities and Towns, which actively represents the interests of the cities vis-à-vis the Federal Government, the Bundestag, the Bundesrat, the European Union and numerous organisations. It advises its member cities and informs them about all events and developments of importance to their communities. It also establishes the exchange of experience between its members and promotes it in numerous committees.

Stuttgart also participates in the Covenant of Mayors, the world's largest movement for local climate and energy actions. The EU Covenant of Mayors for Climate & Energy brings together thousands of local governments voluntarily committed to implementing EU climate and energy objectives. It was launched in 2008 in Europe with the ambition to gather local governments voluntarily committed to achieving and exceeding the EU climate and energy targets. Not only did the initiative introduce a first-of-its-kind bottom-up approach to energy and climate action, but its success quickly went beyond expectations. The initiative now gathers 9000+ local and regional authorities across 57 countries drawing on the strengths of a worldwide multi-stakeholder movement and the technical and methodological support offered by dedicated offices.

In the Climate Alliance Schwäbisch Hall with about 1700 other member municipalities in 27 European states, federal states, provinces, NGOs and other organisations work together actively to combat climate change. Climate Alliance is the largest European city network dedicated to climate protection. The members, from small rural communities to cities with millions of inhabitants, understand climate change as a global challenge that requires local solutions.

The European Energy Award is an international quality management and certification instrument for municipal climate protection, which has been supporting numerous municipalities in Germany and Europe on the way to greater energy efficiency for more than ten years – systematically, in partnership, sustainably. Schwäbisch Hall is proud to have received the golden award of the EEA in February 2019.

Bringing together the relevant actors for climate protection from the region and generating benefits for science, business and local authorities – this is the aim of Teningen and the association "Strategische Partner – Klimaschutz am Oberrhein e. V" (Climate Partner Upper Rhine). As the largest climate protection network in the region, they are currently steering a number of projects that are advancing climate protection efforts in the region by bringing the right partners together: innovative medium-sized companies, universities, research institutions and local authorities are their target groups, whom they support in research and development, in investment projects or in knowledge transfer.

5 Conclusion and recommendation

The introduction and establishment of a well-structured and consistent municipal energy management in Bulgaria is of great importance to make progress in climate protection and resource efficiency. A well-organized municipal energy management can not only help to identify and develop economic saving potentials in municipal properties, which can help to relieve the burden on municipal budgets, but also develop a considerable multiplication potential with a coordinated communication concept. Thus, municipalities can play a pioneering role and set a benchmark as a good example for trade, commerce and services as well as private households.

Based on many years of experience in municipal energy management from Germany, the following success factors and recommendations for the introduction of municipal energy management in Bulgaria can be stated.

- Provision of suitable guidelines, working aids and management tools to support the municipalities in a systematic and consistent approach to the introduction and establishment of municipal energy management. This includes in particular the intelligent organization of municipal energy management as a cross-cutting task by creating clear structures, implementing functioning interfaces and processes as well as a suitable form of communication within the municipal administration.

- Introduction of a national certification system as an external quality assurance instrument that checks the individual implementation phases and the respective fields of activity of municipal energy management on the basis of objective evaluation criteria. In this context, close integration with the European Energy Award as a management and quality assurance instrument for municipal climate protection could be of particular interest.

- Sufficient financial resources should be available for the implementation of measures in municipal energy management. To this end, the creation of a national support program that can be used to finance energy-saving measures in municipal properties should be considered. An established tool for self-financing in Germany is internal contracting.

- The development of specialist skills is of great importance. For example, the establishment of a national organization would be helpful to publicize the advantages and successes of municipal energy management in Bulgarian municipalities and to support the implementation and establishment of the management system with technical expertise.

- Implementation of well-planned pilot projects to make the possibilities and effects of municipal energy management tangible. Schools and kindergartens are particularly well suited as lighthouse projects due to their high multiplication potential. In addition to the high energy savings potential, educational institutions can raise awareness of climate protection issues and sensitize the decision-makers of tomorrow.

- A legal obligation to implement municipal energy management would be one way of ensuring its widespread introduction. However, it should be borne in mind that an obligation imposed from above can also lead to resistance in its daily implementation. For this reason, the complete financing of external consulting services and the free provision of working aids, checklists and guidelines would be a more effective way of exerting influence. The creation of incentive systems and the introduction of a communication campaign could also be a good way of encouraging municipalities to become involved in municipal energy management.

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