A Concept for Comprehensive IT Support for Environmental and Energy Management in SMEs

Anna O'Faoláin de Bhróithe[1], Frank Fuchs-Kittowski[1], Jörn Freiheit[1], Detlef Hüttemann[2], Stefan Voigt[3] and Thomas Dinkel[3]

[1]*HTW Berlin, Wilhelminenhofstr. 75 A, 12459 Berlin, Germany*

[2]*CosmoCode GmbH, Prenzlauer Allee 36g, 10405 Berlin, Germany*

[3]*Fraunhofer IFF, Sandtorstr. 22, 39106 Magdeburg, Germany*

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Abstract: Environmental and energy management (EnvM and EM, respectively) are important aspects in the everyday running of companies. However, there is no single software tool that completely supports companies throughout the entire management process. The aim of the QuiXel project is to develop an integrated data and information platform for evolving and collaborative EnvM and EM in small and medium-sized enterprises (SMEs). The platform will provide comprehensive software support for the complete management process and will simplify tasks such as planning goals and targets, data structuring, data acquisition, data analysis, report generation, and documentation. In addition, the platform will provide an integrated manual providing instructions and guidelines for the best practice of EnvM/EM in accordance with the ISO 14001 and ISO 50001 norms. The requirements for such a platform are presented in this paper, along with an overview of the system concept.

1 INTRODUCTION

Small and medium-sized enterprises (SMEs) can gain significant benefits from implementing energy management; they can reduce their costs, protect the environment, increase the sustainability of the economy, and improve their public image (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU), 2012). However, many tasks covering a broad range of areas including documentation, control, planning, monitoring, evaluation and decision-making must be fulfilled as part of a complete energy management process. It is not possible to successfully implement energy management without the support of appropriate tools as the tasks are too numerous and too complex (Wohlgemuth, 2015). It is noteworthy, then, that no single software tool capable of supporting all these tasks currently exists (EnergieAgentur.NRW, 2013). At present, only certain aspects of the management process are addressed by specialized software solutions, e.g., energy data management or energy control (Rößler et al., 2013). A single tool capable of guiding users through the complete process as well as managing all necessary data (including documentation, raw data, analysis results, and reports) would be helpful for experienced environmental and energy managers as well as for beginners.

The QuiXel project, funded by the BMBF "KMU-innovativ" program, is pursuing a comprehensive approach to providing complete IT support throughout the management process with a single platform. Based on the European norms for environmental management (EnvM) and energy management (EM) as well as discussions with industry partners, the requirements for such a system have been determined and consequently integrated into an all-inclusive concept. The platform must aid in a multitude of tasks such as planning efficiency measures, setting goals and targets, data structuring, data acquisition (both manual and automatic), data analysis, reporting, and documentation. The system should also provide information and instructions to its users on EnvM/EM best practices so that non-experts can quickly start making progress. These instructions should be compliant with ISO norms for EnvM and EM so that users who follow the guidelines are eligible for certification. The project is currently in the implementation phase, with the testing and evaluation phase to be completed by

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This paper is structured as follows: Section 2 presents the current status of technology in the area of tool-assisted energy management in SMEs. Section 3 discusses the procedure used to perform the requirements analysis for software support of the complete EnvM/EM process. The concept derived from this analysis is presented in Section 4. The paper concludes with a summary and outlook on the continuing work in the project.

2 TECHNOLOGICAL STATUS AND RELATED WORK

The main tasks of industrial environmental information systems (IEISs) are to provide information and documentation, support evaluation and decision-making, and enable control, planning, and monitoring throughout the management process (Wohlgemuth, 2015). Software solutions are available for each of these tasks, however, usually as separate, isolated applications or stand-alone systems (Heldt and Wohlgemuth, 2009). Established definitions of IEISs, for example (Wohlgemuth, 2015, S. 224), only require partial support for environmental and sustainability management tasks, as no comprehensive solution exists.

The European norms for energy management (ISO 50001) and environmental management (ISO 14001, 14004, 14006, 14031, 14044, and 14063) do not provide explicit instructions for implementing and executing EM/EnvM in specific cases, but rather pertain to the general process that is followed. Corresponding handbooks such as (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU), 2012; Sächsische Energieagentur SAENA GmbH, 2015; Umweltgutachterausschuss (UGA), 2011) provide organisational guidance and recommendations, but do not offer any tool support. Additionally, SMEs generally lack financial and human resources, as well as knowledge and experience in the area of implementing such systems (Eichhammer et al., 2011). Software support — i.e., the use of IEISs — is therefore necessary for processing environmental and energy data for administration, analysis, visualisation and simulations (Hilty and Rautenstrauch, 1995).

Model-based approaches, such as that presented in (Rößler et al., 2013), provide helpful support in the form of a manual or reference process for implementing energy management. Similar to the system proposed in this paper, model-based approaches are based on a detailed analysis of the requirements presented in the norms and therefore ensure a formally valid implementation of energy management. However, they lack any tool-based support for analysis, visualisation, or simulations.

Currently, IEISs are mainly used to ensure legal compliance, provide support for EnvM, and collect and display data (Wohlgemuth, 2015). However, the present trend is to take material aspects (raw materials and energy consumption) into account alongside the classical control parameters of the production simulation in tactical and strategic problems (Wohlgemuth, 2015). Accordingly, attempts are being made to utilise and further develop pre-existing information resources and applications in companies in order to achieve this (Boß and Wohlgemuth, 2015). The open-source tool "OpenResKit-Framework" has similar goals, but mainly concentrates on the integration of existing data and information (Boß and Wohlgemuth, 2015) and is therefore focused on providing information and documentation (Wohlgemuth, 2015). In the area of analysis and decision-making support, the tool "e!Sankey" is used in conjunction with a Microsoft Excel® table to visualise energy, material, or cost flows (Boß and Wohlgemuth, 2015). Even the application of the OpenResKit-Framework to learning energy-efficiency networks (Schneider et al., 2014) does not pursue a comprehensive approach to supporting all aspects of the management process, but instead focuses on the areas of information and documentation.

The QuiXel project, presented in this paper, attempts to provide an all-inclusive approach to supporting EnvM and EM by addressing the areas of planning, data structuring, data acquisition, analysis, visualisation, and documentation. Guidelines that are compliant with the European norms will also be provided within the system in the form of a platform-integrated manual so that the necessary expertise is always readily available without the need to consult external resources.

3 PROCEDURE FOR REQUIREMENTS ANALYSIS

In order to assess the requirements for comprehensive IT support of the entire EnvM/EM process in SMEs, a model of the work packages necessary for obtaining certification was first drafted based on the ISO 50001 (DIN, 2011) and ISO 14001 (DIN, 2015) norms. This model is shown in Figure 1. The numbers of the work packages correspond to the section numbers of the respective norm.

In the next step, a refined model was created by further detailing all work packages according to the norms. This ensured that all necessary functions for

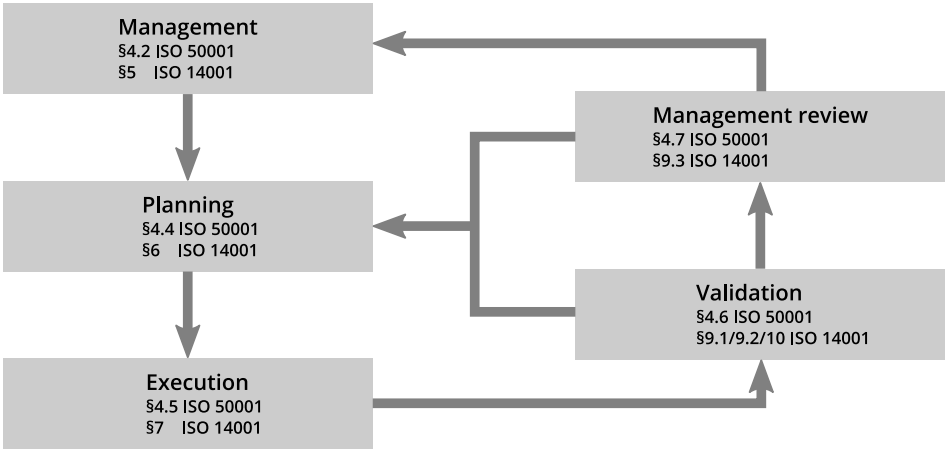

Figure 1: Implementation and operation of EM and EnvM systems.

all work packages were taken into account and resulted in a detailed list of requirements for the software system. Figure 2 shows the details of the "Planning" work package as an example. The numbers of the subpackages also reflect the numbering of the relevant subsections in the norms.

Workshops were then held with pilot users of the platform based on the refined model. The workshops addressed, in particular, the question of what type of software support could be expected for which tasks. Functional "focus areas" were identified during the workshops by considering all the tasks in the context of different *use cases*.

4 REQUIREMENTS AND CONCEPT

Based on the refined model, a requirements catalogue for the entire system was collated. These requirements were categorised according to the individual work packages as shown in Figure 1. One further category "General/other" was defined to cover the remaining requirements, such as user management. The full list of requirements is briefly presented below.

Management

- *A1.1 Team definition:* It shall be possible to define and document the EnvM/EM team and differentiate between different roles (e.g., manager, member).
- *A1.3 Configurability:* The system should provide a customised experience to the user in terms of information provided and task emphasis based on the target level of EnvM/EM (e.g., if certification is sought or not).

Planning

- *A0.3 Action plan creation:* The platform shall include a function to designate and describe efficiency measures, i.e., an action plan.
- *A0.4 Action plan maintenance:* It shall be possible to edit the action plan. It should be possible to document the status of the edits.
- *A1.2a Goal definition:* It shall be possible to define and document individual goals.
- *A1.2b Goal specification:* It shall be possible to differentiate between strategic and operative goals.
- *A1.2c Goal designation:* It shall be possible to link operative goals with any number of associated strategic goals.
- *A2.2.1a Acquisition of variables:* The energy manager and the energy team shall be able to collaboratively define a variable (e.g., a meter such as a gas, water, or electricity meter) with the aid of real-time hints from the system (tooltips).
- *A2.2.1b Description of variables:* The energy manager and the energy team shall be able to add a text description to variables.
- *A2.2.1c Authentication of variables:* The energy manager and the energy team shall be able to authenticate variables in order to make them available for further use in the system.
- *A2.2.1d Templates for variables:* It should be possible for the energy team to reuse already-defined variables as well as save variables as templates in order to use these as the starting point for subsequent definitions.
- *A2.2.2 Structuring of variables:* Single variables shall be available for evaluation in different combinations/structures.

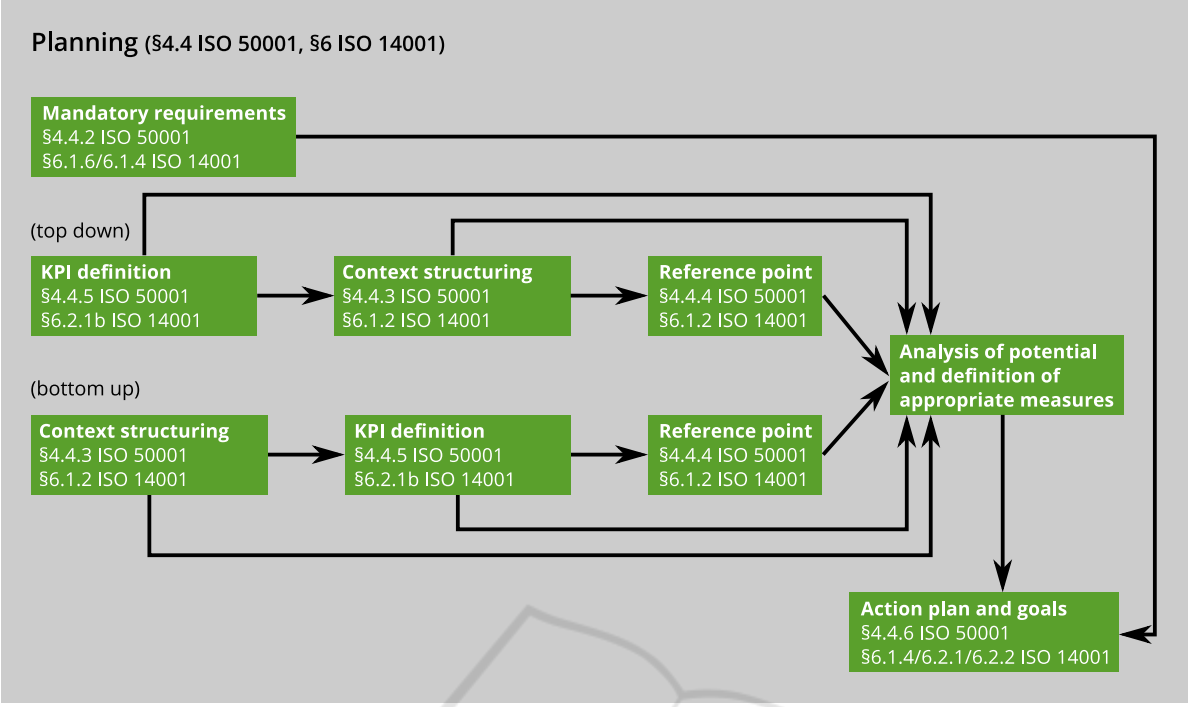

Figure 2: Detailed view of the "Planning" work package.

- *A2.2.3 Evolving collaborative process:* It shall be possible to continuously develop energy and environmental key performance indicators (KPIs) via an iterative process of collaborative discussion and negotiation, as changes to company goals as well as in company structure lead to changes in the structure of the data and the variables.
- *A2.2.4 Release procedure of final model:* It shall be possible for the team to organise the collaborative work process over multiple hierarchical levels. Only the highest level of the hierarchy shall have the right to validate and release the model consisting of the structured variables and KPIs produced throughout this process.
- *A2.3.1a Selection of reference data:* It shall be possible to define a reference data set to be used as a comparison for the current review period.
- *A2.3.1b Comparison with reference data:* It shall be possible to calculate KPIs for the reference period as well as the current review period.
- *A2.4.1 Assigning KPIs to defined goals:* It shall be possible to link individual KPIs to one or more goals set forth in the action plan.
- *A2.4.2 Bottom-up KPI definition:* It shall be possible to define KPIs by selecting and aggregating a set of suitable variables from those already defined in the system.
- *A2.4.3 Top-down KPI definition:* It shall be possible to define KPIs and then check if all necessary variables are available in the system.
- *A2.4.4 Definition of KPIs as a function of the variable structure:* It shall be possible to define KPI as a function of variables. For this purpose, it shall be possible to define the mathematical equation for calculating the KPIs in a formula editor using mathematical operations and multiple variables.

Execution

- *A0.1 Dashboard:* It should be possible to see an overview of the current status of individual management tasks.
- *A3.3.1 Documentation of the EnvM/EM process:* It shall be possible for the team to document the EnvM/EM process in a collaborative manner.
- *A3.4.1 Reading of data from external systems:* In order to maintain existing business processes, it shall be possible to read data from external systems (e.g., Tekla, SteelOffice).
- *A3.4.2 Raw data import:* It shall be possible to import meter readings from existing spreadsheets or tables.
- *A3.4.3 Manual data entry:* The system shall facilitate manually saving a reading from a meter defined in the system. An appropriate, standardised

input form containing information about the meter as well as an input field for the meter reading shall be provided for this purpose.

- *A3.4.4a Data quality control:* The platform shall continuously check if the data in the system are complete, i.e., measurements for all defined meters arrive at the expected times.
- *A3.4.4b Data quality alerts:* The system should notify the responsible person if data are missing for a particular meter or for a given time period.

Validation

- *A5.1.1 Creation of reports:* The system should automatically create reports allowing an evaluation of the data from the defined KPIs and/or data on-hand in the system. The report shall be available both in a format that is easily viewed on-screen as well as in a print-ready format (e.g., pdf).
- *A5.1.2a Comparison of results with reference data:* The system shall be able to compare the data and KPIs from the current review period with those from the reference period.
- *A5.1.2b Comparison of results with reference data failure alert:* If the current KPIs cannot be calculated for the reference period, the system should report that the chosen reference period is no longer valid.
- *A5.1.3 Analysis of review period:* It shall be possible to assess the data with respect to the goals defined in the action plan.

Management Review

- *A5.4.1a Measures for improvement:* The system shall allow a review of the current review period with respect to the goals set out in the action plan.
- *A5.4.1b Documentation of measures:* It shall be possible to document progress towards the different goals.
- *A5.4.1c Continuous improvement:* It shall be possible to define new efficiency measures, and to extend or amend those that already exist based on the most recent results.

General/Other

- *A0.2 Administrative functions:* An administrator shall be able to add, change, and delete users from the system, as well as control user rights. In the case that the system comprises multiple components requiring user authentication, a *Single Sign On* is desirable.
- *A0.5 Model export:* It shall be possible to export the validated data model (structured variables and KPIs).
- *A0.6 Model transformation:* It shall be possible to generate a formal description of the data model.
- *A0.7 Model storage:* It shall be possible to save the data model in a formal manner (e.g., in a relational database).
- *A0.8 Integrated manual:* The system shall provide instructions and guidelines for the best practice of EnvM/EM in the form of a platform-integrated manual.

4.1 Overall Concept

The overall concept developed from the requirements is depicted in Figure 3. The figure is split into two distinct layers: the top layer of pictograms shows the necessary tasks and the bottom layer represents the actions that must be performed by one or more of the system users in order to complete the steps shown in the top layer. The corresponding requirement ID is written in grey beside each task or action. Except for documentation, all tasks are grouped according to their work packages (and therefore according to the specific areas described in the ISO norms). Documentation — shown in Box A — is instead visualised as a continuous task that is supported throughout the entire management process with input coming from other tasks that are performed in parallel.

Box B "Management" represents the task of choosing the target level of EnvM/EM to be implemented. The system should be automatically adapted according to the chosen target level (e.g., a company that wishes to be certified will require much more rigorous procedures and documentation than a company that only wishes to reduce its electricity costs). In particular, this includes configuring the guidelines that are presented to the user as well as selecting which documentation the user is obliged to produce.

Box C shows the individual steps that must be completed in the "Planning" work package. The steps correspond to those from Figure 2, and are embedded here in a *use case* that describes the entire process of energy and environmental management.

The actual data is collected in "Execution — data acquisition" (Box D). Data can be acquired by the system from manual user input (collaborative data entry), by automatically collecting data provided by electronic meters, or by importing raw data from other sources (e.g., enterprise resource planning systems).

In the "Validation" work package (Box E), reports are generated that can then be made available to the

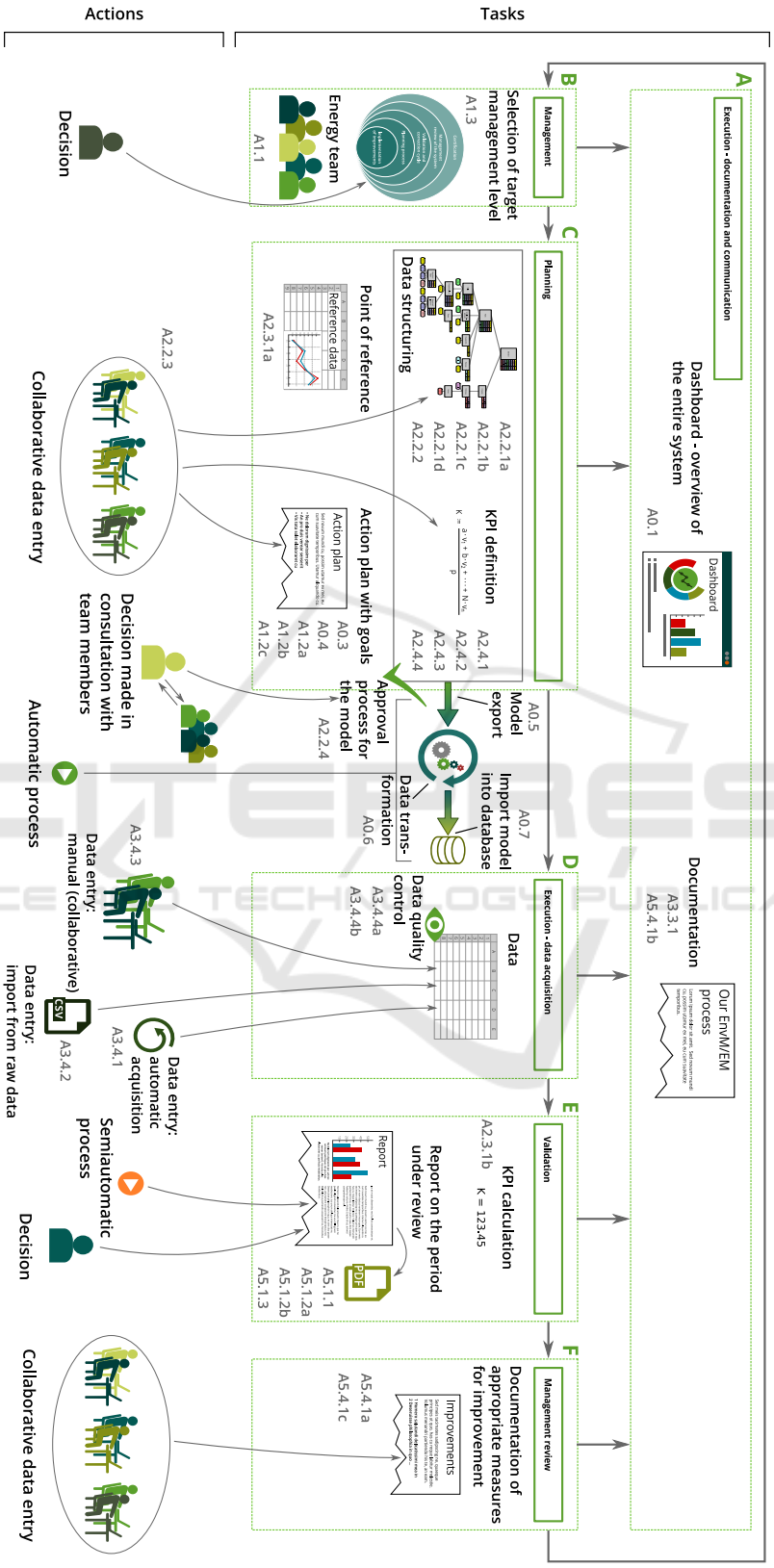

Figure 3: Illustration of the overall concept of the system.

decision-makers. The reports include the calculated values of the KPIs that were defined earlier in the "KPI definition" step (see "Planning", Box C). These values are calculated using the data collected in Box D.

An automatically generated (and adapted) data model is a necessary interface between the "Planning" and "Execution — data acquisition" work packages in order to ensure data consistency and to facilitate the collection of the data necessary for the analysis. This data formalisation process does not require any input from the user and therefore takes place in the background.

Overall, the system offers a comprehensive approach to EnvM/EM in which the level of management can be iteratively improved by adapting the action plan and efficiency measures in the company based on the information contained in the reports and the documentation (see "Management review", Box F).

4.2 Technical Concept

In a technical sense, the system must provide two basic functions: it must support collaborative content modification (e.g., documentation and KPI definition) as well as facilitating data acquisition and analysis. A structured wiki could provide a technical basis for collaborative KPI definition. On the other hand, a spreadsheet is the best solution for the data acquisition, as this provides a familiar environment for data entry. One option is to create a system using existing wiki and spreadsheet software as front ends to a common database. However, this is an inelegant solution, as the workflow is split across multiple front ends/user interfaces and it is difficult to define exactly what information should be entered from which interface without making a somewhat arbitrary divide in the work process.

Although more implementation-intensive, a custom front end containing both wiki-like elements and spreadsheet-like elements as needed provides a much better interface to the system. With this solution, users can complete all aspects of the entire EnvM/EM process from a single, unified front end. It is therefore planned to realise the user interface as a custom-built web front end. To ensure multi-user capability (collaboration) and data consistency, this front end will be connected to a central database back end. An export/import function to/from popular spreadsheet formats (e.g., csv, LibreOffice Calc or Microsoft Excel®) is a feasible addition that would allow users to acquire data with well-known and widely used software (Junker, 2010; Leyh et al., 2011).

Another focus area is the configurability of the process depending on the objectives of the company. The scope and level of detail of the management process should be adapted to the goals and needs of the specific company. It is planned that the company initially identifies its EnvM/EM goals and on this basis, the system offers a tailored process for the company to follow, i.e., the guidelines and documentation templates are adapted based on the company's management targets. In addition, the KPI definition component is configured in such a way that the complexity of the KPIs corresponds to the user's goals. Customer-oriented step-by-step instructions and tailored documentation templates are provided. Since the model beneath this system configuration contains all the essential aspects of the European EnvM and EM norms, it is ensured that the management process is carried out in accordance with regulations.

5 SUMMARY AND OUTLOOK

This paper presents the central concept of the QuiXel project: an integrated data and information platform for collaborative and evolving environmental and energy management in SMEs. The need for comprehensive IT support for all aspects of EnvM/EM is discussed.

The requirements for such a platform are derived from a detailed analysis of the European environmental and energy management norms as well as from workshops held with potential industry partners. A catalogue of essential functional requirements for a comprehensive EnvM/EM system is presented. A sketch of the technical concept, based on this catalogue, is outlined.

The project is currently in the implementation phase. A prototype platform will be delivered to the industry partners by mid-2018 for testing and evaluation. The software will be improved based on input and feedback from the pilot users and the final evaluation phase will be concluded by the end of 2018.

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