Co-funded by the
Erasmus+ Programme
of the European Union

Smart Energy Mangagement (SEM): Approach, relevance, and online learning modules

What is Smart Energy Management (SEM) and what relevance does it have for industrial-technical work? This question is being investigated by a European consortium of seven players as part of the "Energyducation" project. The paper presents findings from this collaboration. This includes the interpretation of the term SEM for skilled work, a SEM qualification profile as well as the evaluation of the relevance of SEM for German training occupations. Finally, freely available online learning modules for vocational training are presented, which were developed in this project.

1. The project "Energyducation"

In view of the climate debate, the European Commission already set binding targets for all member states in 2011 on how CO2 emissions must be reduced to prevent global warming from increasing further (European Commission, 8.3.2011). In addition to avoiding the burning of fossil fuels, the European Parliament, and the European Council (25.10.2012) also focus on minimizing energy consumption. By using energy management systems (ISO 50001), energy consumption can be recorded, monitored, and controlled. For energy management systems to develop their savings potential, large energy consumers must record their consumption in a standardized manner and explain which solutions - including which energy management systems - they will use to reduce it. This requires technical expertise and the application of energy-saving processes. They can be summarized under the term "Smart Energy Management", although the definition of the term must be assessed as not finalized (Großmann, Kunold & Engels, 2018).

Considering this situation, a consortium of seven stakeholders asked themselves the following questions: How can the broad term "Smart Energy Management" (SEM) be defined? What is the significance of SEM for skilled industrial-technical work? What qualifications do skilled industrial-technical workers (EQF, 4) need for SEM? How can these skills be promoted online?

These questions were addressed by teachers from the vocational school CIFP Usurbil LHII (Spain), the foundation ZubiGune Fundazioa (Ursubil, Spain), the Institute for Vocational Teacher Education (IBL) of the University of Applied Sciences Münster (Germany), the vocational school Alfa-College (Groningen, Netherlands), the vocational school Lulea Kommun (Luleå, Sweden), the vocational consulting company NTI-MMM (Oslo, Norway) and the foundation myclimate (Zurich, Switzerland). The overall goal of the joint project Energyducation, which was co-funded by the EU through the Erasmus+ program (grant number KA202; project duration: 1.10.2018 to 30.06.2021), was to prepare SEM for industrial-technical technical work and to transfer the findings to vocational education institutions to make an active contribution to minimizing energy consumption in the EU. The key results of the project are presented below and are also freely available on the project website: www.energyducation.eu.

2. SEM: Approach to a challenging issue

For the approach to the term "Smart Energy Management", the expertise of the international actors involved in the project as well as the results of a survey of SEM experts were incorporated. Both the project partners and the interviewees have different experiences about SEM in the technical domains of Lighting, Smart Grid, Smart Metering, Thermal Installation and UX Design, which enabled a broad approach to the topic. The following SEM definition was created about the technical work (EQF level 4):

Smart Energy Management helps to save energy in conversion, storage, distribution, and consumption units by strategically influencing user behavior and energy flows through the intelligent interaction of sensors, actuators, controllers, and user interfaces.

Tab. 1: Definition of SEM for skilled work (EQR level 4)

For this definition - and a qualification description presented below - the project partners exchanged their own experiences and competencies about SEM via video conference as a first step. The four presentations lasted one to one and a half hours and were recorded. This was followed by interviews with SEM experts (service providers, R&D, industry). The interviews were conducted along six guiding questions derived from the European Qualification Framework (EQF), e.g., "What do you think a SEM expert in EQF level 4 needs to know?" The answers were recorded in the form of written notes and assigned to the guiding questions. A total of ten SEM experts were interviewed in four countries (DE, ES, NL, SE) and the interview results were transcribed into a common text document. Following on from the results, each location developed its own definition for SEM as well as a qualification description for SEM experts. These were presented in a joint video conference. The SEM definitions and SEM qualification descriptions could be read in advance, were then discussed in the video conference and subsequently modified. Based on these four results, the IBL of Münster UAS developed a common SEM definition and SEM qualification description, presented it for discussion in another videoconference and worked in the desired modifications. Subsequently, the common SEM definition and SEM qualification description were translated into seven other European languages by the partners (GER, EUS, FR, ES, NL, SE, NO), submitted in writing to eight SEM experts in their native language and feedback was obtained. The change requests from the feedbacks were incorporated into the English version and then translated into the other European languages. This resulted in the final SEM definition in Table 1 and the SEM qualification description in Table 2, which provide orientation for teachers and were used by the project partners as a basis for planning the online learning modules.

Knowledge
An SEM expert has knowledge ...
... of energy conversion, energy storage, energy distribution and energy consumption units.
... with regard to the operating principle of Smart Energy Management Systems (hardware/software) as an interaction of sensors, actuators, controllers, communication technologies, user interfaces and user behavior.
... about strategies to save energy.
... about data protection regulations, energy regulations as well as sustainability regulations on regional, national, European, and international level.
Skills
An SEM Expert is able to…
... analyze energy generation, energy distribution, energy storage, energy consumption units, and user behavior based on plans and site visits and interviews.
... develop new energy-saving methods or optimize an existing Smart Energy Management System on the basis of an analysis carried out, taking into account a cost-benefit analysis.
... implement a Smart Energy Management System, document it, hand it over to non-technical people and maintain it.
Competencies: Responsibility & Autonomy
An SEM expert is able to ...
... depending on the complexity, perform tasks related to Smart Energy Management Systems independently or according to instructions, alone and in a team.
... depending on the complexity, independently or according to instructions, carry out tasks related to Smart Energy Management Systems in an inter-institutional as well as interdisciplinary cooperation.

Tab. 2: SEM qualification description based on the EQF

3. Relevance: The importance of SEM for skilled work in Germany

The high relevance of SEM identified by the European project partners in their national contexts raised the question for us as a German project partner, who had expertise in technology didactics and not directly in SEM, of what significance SEM has for technical work in the Federal Republic of Germany? Initial research revealed that extensive work on SEM had been done as part of the "Virtual Institute Smart Energy (VISE)" project, which was supported by seven universities and divided into four subprojects: business models, households, companies, and virtual power plants. This research and development project, which was funded by the European Union and the state of North Rhine-Westphalia, came to an end at the end of 2020 and showed that SEM can benefit not only energy utilities, but also small and medium-sized enterprises and end customers, e.g., with photovoltaic systems. Participation in the 2019 and 2020 annual conferences on our part revealed a broad interest in SEM across industries, which coincided with the expertise of our European project partners. Further projects as well as public funding opportunities for companies to implement SEM in their business (Federal Ministry of Economics and Export Control, 2020) could be identified. A widespread discussion of SEM in professional work could be sighted (Tärre, 2019; Piening, Müller & Sander, 2017; Hägele, 2014; Heinen & Frenz, 2014), but a close discussion could not be observed. To date, it seems that SEM is predominantly addressed in the R&D context as well as on a strategic company level, and about industrial-technical skilled work, our European project partners have positioned themselves early.

Based on these findings, we looked for points of reference in the framework curricula of industrial-technical occupations to evaluate the relevance of SEM for skilled work in Germany. For this purpose, in a first run, all occupations were screened that are linked to the vocational specializations that are jointly trained by Münster University of Applied Sciences and the Westphalian Wilhelms University of Münster in industrial-technical teacher training. These are the vocational specializations of civil engineering, electrical engineering, information technology, mechanical engineering technology and - as a half-technical, half-design specialization and North Rhine-Westphalian specialty - media design/design technology. We examined the framework curricula for these occupations and looked for points of contact based on the SEM definition and the SEM qualification. Based on this, the occupations were subjected to a closer examination and learning fields were sifted that could be linked to SEM. Table 3 provides an overview of the identified occupations and learning fields.

Vocational specialization	**Occupations (learning field no.; specialization, if applicable) with in-depth review of framework curricula**
Electrical engineering	• Electrician (2, 3, 4, 5) • Electronics technician for automation technology (3, 4, 7, 9, 10, 12) • Electronics technician for operating technology (3, 4, 7, 9, 10, 11) • Electronics technician for building and infrastructure (3, 4, 7, 8, 9, 13) • Electronics technician for devices and systems (3, 4, 7) • Electronics technician for information and systems technology (3, 4, 6, 7, 8, 9, 10, 11) • Electronics technician for machine and drive technology (3, 4) • Electronics technician (3, 4, 7, 10 EG, 11 EG, 12 EG, 9 A, 10 A, 12 A) • Industrial electrician (3, 4, 7 BT, 7 GS) • Information electronics technician (1, 7, 8, 9, 10 GS, 14 GS, 16 GS) • Systems electronics technician (3, 4, 7)

	• Technical systems planner (5 VAT, 11 VAT, 13 VAT, 6 ETS, 7 ETS, 9 ETS, 11 ETS)
Information technology	• IT specialist (5, 9, 10a, 11a, 12a, 10b, 12b, 10d, 12d) • IT systems electronics technician (5, 9) • Mathematical-technical software developer (9, 11, 13)
Metal technology (in NRW mechanical engineering technology)	• Plant mechanic (10) • Plant mechanic for sanitary, heating and air-conditioning technology (7, 12, 14) • Industrial mechanic (13) • Mechatronics technician (5, 9) • Mechatronics technician for refrigeration technology (9, 14, 15, 16)
Media design / Design technology (NRW)	• Digital and print media designer (5, 13b, 12d, 13d)

Tab. 3: Points of contact for SEM with industrial-technical professions in Germany

Since there are several connecting points across the occupational disciplines, cross-professional (cross-trade) collaboration is also recommended. A smart home, for example, could serve as a learning model for this: The installation and planning of the technology, including control and regulation systems, are carried out by an electronics technician. The software used to network the hardware is programmed by an IT specialist and the graphical user interface is created by a media designer. In addition, the control of heating and ventilation systems could be included, which would allow cooperation with plumbing, heating, and air conditioning technicians.

In summary, a visible relevance can be stated for industrial-technical professions, which means that, from our point of view, the thematization of SEM in the relevant vocational training institutions is recommended.

4. Open Educational Resources (OER): Learning Modules and Terms of Use

Based on the SEM definition and the SEM qualification framework, online learning modules were developed for different professional fields of activity. These fields of action resulted from the respective expertise of the project partners and thus by no means represent all conceivable fields of action for SEM. The contents of the online learning modules are described below; the respective authors are named in parentheses:

- Introduction to SEM (IBL): This learning module addresses climate change and the need to save energy. The basics of smart energy management are developed (interaction of sensors, actuators, controllers, communication technologies, user interfaces and user behavior) and different professional fields of action (grid, home, metering, standards) are shown as well as what an SEM expert must know and be able to do. The intention is to show students that they can contribute to climate change mitigation through their professional expertise. This learning module serves as an introduction to all other learning modules.

- Thermal Installations (CIFP Ursubil LHII): In this learning module, students are introduced to an SEM system that controls thermal and electrical energies. Students learn the basics of measuring energy (use of sensors, analysis of measured data) and are thus later able to determine energy balances and efficiencies as well as define energy saving parameters.
- UX Design (ROC Alfa-college): To operate a Smart Energy Management System, a user interface is required. The learning module deals with the creation of such a user interface and accompanies the students through its creation and development, considering the user experience (UX). In the process, they learn about design thinking methods (Maslow of Design, User Flow), create various prototypes (digital as well as pen and paper), and learn how to use user interface design software and design libraries.
- Lightning (ROC Alfa-college): it is easy to save energy through smart lighting. In this course, students will learn about different types of lights and methods to control them intelligently. Finally, a prototype of a smart lighting system will be created and presented (*This learning module is currently in progress and is expected to be completed by the end of the project*).
- Energy Mapping (Lulea Kommun): Energy is needed and consumed in many places in buildings. These include heating and air conditioning, ventilation, electrical, and lighting. These points all have a high energy-saving potential, which can be achieved through optimization. How energy can be saved at these points through intelligent control is to be presented in this learning module (*This learning module is currently still in progress and will probably be completed by the end of the project*).

All learning modules are written in English, the module "SEM introduction" has meanwhile been translated into German by the initiative of the Swiss project partner myclimate. All actors have tried to use simple English language; explanations spoken in videos are sometimes also available as text and subtitles in the video (cf. Figure 1) and can thus be read. For accompanying English lessons, the videos also have the advantage that they can be paused and passages that are not understood can be watched again. The learning modules are methodically structured along the lines of problem-based learning: 1) Statement of the problem 2) From problem to project 3) Gathering information 4) Identifying possible solutions 5) Evaluating solutions 6) Planning a solution to the problem 7) Implementing the solution and 8) Presenting the results (see Figure 2). The individual phases are student-centered and transfer the teacher into the role of learning guide. For this purpose, the phases are designed differently, e.g., information is presented in the form of small lectures, work assignments are carried out in teams, teamwork is organized e.g. with an Etherpad, results are presented via own lectures and the possibility is continuously given to check the own level of knowledge by self-learning tests. In addition, all learning modules include instructions for the learners as well as for the teachers (including an assessment grid). To enable easy recognition of learning outcomes between EU educational institutions, the learning modules are also documented as learning units according to the ECVET model (Reglin, 2011).

The learning modules were used several times in class, evaluated and modified. Finally, they were made available to the public on the learning management system ILIAS of Münster University of Applied Sciences. They can be viewed there; access can be found on the project website (www.energyducation.eu). In this public version, all interactive elements are deactivated for security reasons. However, interested teachers can write to us and get access to the complete learning modules. The learning modules are offered as Open Educational Resources (OER) and can thus be used and modified by any teacher (including translated into their own language). For a permanent use the transfer of the learning modules into an own learning management system is necessary. ILIAS provides appropriate export functions for this purpose. If the transfer into the own digital learning environment is not possible, a reconstruction can be accomplished with a manageable effort, whereby many digital artifacts of the present ILIAS version can be taken over.

5. Conclusion: SEM is also a learning instrument for sustainability education.

The cooperation of the European project partners made it possible to narrow down SEM for industrial-technical skilled work by developing a common SEM definition and a SEM qualification description. Based on this, connecting factors were identified for skilled work in Germany and the relevance of SEM was assessed for the first time in a national context for skilled work. The online learning modules developed in the project have now been tested several times and are available as Open Educational Resources (OER). A transfer into own digital learning environments is necessary for this, an adaptation of the learning modules is thereby possible.

In this way, SEM has opened a vocational field of action for industrial-technical work in vocational training that enables students to use their technical expertise to make contributions to reducing climate change. In the age of "Fridays for Future", SEM thus offers a learning vehicle that is sure to tap into an intrinsic motivation in many students and thus also contribute to sustainability education. Likewise, in view of the goals set by the European Union for minimizing energy consumption, a thematic approach on the part of vocational training seems desirable to train qualified skilled workers for these ambitious goals.

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The article appeared as gray literature in the German journal "lernen und lehren" and is citable.

Krüger, M.; Stallmeier, N.; Wösten, H.; Schäfer, F. (2021): Smart Energy Management (SEM): Annährung, Relevanz und Online-Lernmodule. In: *lernen & lehren*, Heft 144 (4), 36. Jahrgang.