# What's going on in energy efficiency research? A platform to enhance the transparency of energy research funding in Germany


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## Abstract

Public funding of energy research projects is a major pillar for developing new energy-efficient technologies and concepts. With European energy and climate targets driving such projects, it is becoming challenging to keep up with their ever-increasing number. Our contribution demonstrates how combining the expertise on energy efficiency and renewable energies, linguistic text processing and modern information technology can help to respond to this challenge and thereby render research funding more transparent and accessible to the public. We provide an overview of the German energy research funding information system 'EnArgus'. This web-based system makes it possible to intelligently review and cluster the vast number of publicly-funded energy research projects in Germany carried out since 1970. The core element of the system is an ontology-assisted search engine derived from more than 2,200 short articles, which were specifically prepared for this purpose. These texts cover energy technologies as well as the related basic terminology and concepts. To illustrate the system, we provide an overview of its structure, its main components and a summary of its evaluation as well as important lessons learned from the project. The results of the evaluation indicate that the system is well suited to help structure and access the growing number of publicly-funded energy research projects.


## Introduction

Funding national and international research projects on energy efficiency and renewable energies is an important policy option for enhancing the transition towards a low-carbon economy. With European energy and climate targets driving such projects, it is becoming difficult to keep up with their ever-increasing number. This is necessary for numerous reasons, e.g. to account for the utilization of public funds, identify research trends or gaps and avoid repeated spending on similar topics.

The introduction of database systems for managing energy research projects over the last decades, though often mainly intended for administrative purposes, has considerably simplified information processing in this area. Yet simple plain text matching queries have limitations when investigating energy research activities: If, for example, there is a need to identify research activities on 'electric drives', projects dealing with 'electric motors' or 'electric propulsion' are easily omitted if these search strings are not explicitly specified or included in the project databases. Furthermore, to obtain a complete picture of the relevant research, it might be necessary to review, e.g. projects dealing with specific components of drives such as 'gears', related energy-efficiency measures such as the utilization of 'frequency converters' or applications of drives such as 'compressed air'. While it is possible to think about the proper terms manually, this process is time consuming and requires the user to have some level of expertise in the topic.

Combining knowledge on energy-related topics, linguistic text processing and modern information technology can facilitate such tasks and thereby make research funding more transparent and accessible to a wider audience. This paper illustrates how this approach was put into practice using the example of the centralized German energy research system 'EnArgus'.

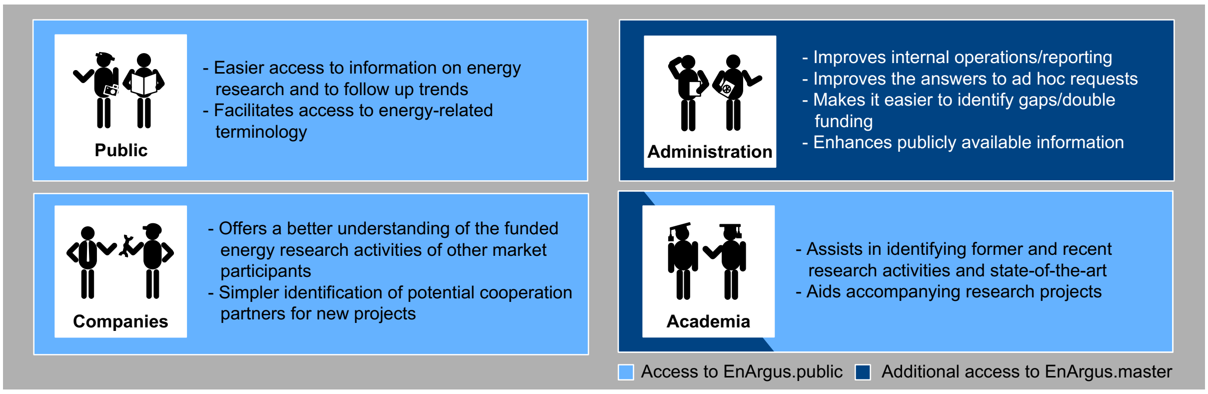



*Figure 1. Target groups and their potential benefits from the system.*

In the following, we briefly introduce the system and describe its main components. Then we provide a short summary of the main findings of a recent evaluation and some lessons learnt from the development process.

## The EnArgus system

From a historical perspective, information on federal energy research funding in Germany is distributed across several databases. These systems have limitations when reviewing activities in energy research: 1) They were mainly designed for administrative purposes rather than content-wise follow up. 2) Information on public funding is rarely accessible to the public. 3) Projects are often clustered according to administrative categories although they deal with broad(er) topics. 4) Project reports are not directly accessible from the databases. 5) Search strategies are typically based on plain text matching. 6) It is tedious to obtain answers even to simple questions like 'Who has actually received funding for research on 'electric motors' during the last decade?'

The centralized energy research funding system EnArgus has been developed to overcome these limitations and help public administrations, academia, companies and the public access information related to energy research funding (Figure 1). The system was developed in two phases in a joint effort by energy researchers, IT experts, computer linguists and public administrators: The first demonstration system was developed between 2011 and 2013; followed by a phase of extensions and deployment from 2013 to 2017, which culminated in 'EnArgus2.0'.

The starting point of the EnArgus project was an analysis of the needs of different user groups. This resulted in a priority list of the requirements made of a centralised energy research funding system (see Hinrichs et al. 2015; Oppermann et al. 2015). Based on these requirements, a web-based application consisting of two systems was designed: 'EnArgus.public' is open to any web user; 'EnArgus.master' is a restricted system for proficient users mainly addressing public administration. It can also be accessed by academia in specific contexts, e.g. accompanying research projects. While EnArgus.public focuses on a simple and intuitive user interface, EnArgus.master allows more refined data analysis, visualization and access to restricted administrative data.

Figure 2 shows a simplified system overview highlighting its major 'services' as well as the underlying 'back-end' processes based on a modified BSCW[1] system. The methodological idea of the system can be summarized as follows: The core of the system is a domain-specific ontological database on energy research, i.e. a means to represent knowledge on energy research using a collection of domain-specific terms and relations (for details, see below). To develop this database, energy researchers prepared dedicated short texts on energy-related research topics. Computer linguists then processed these texts using semi-automated text processing to create an ontological database. Search queries to the system can finally access this database to enhance the data retrieval process. In the following, we further explain the key components of the system.

### WIKI & COMPENDIUM

The EnArgus wiki is a collection of more than 2,200 short texts (max. 6,000 characters) in German covering basic terminology, concepts and technologies from the domain of energy research (Figure 3a). Energy researchers from different fields of expertise prepared these texts. They cover the entire range of energy research topics including technologies related to energy efficiency (e.g. processes, technologies, appliances, buildings), renewable and conventional energy sources (e.g. geothermal power, photovoltaics, biomass, thermal power plants) and power transmission (e.g. electric grids, district heating) as well as basic terminology (e.g. from material or energy science) and concepts (e.g. sustainability, energy models, policy instruments). The purpose of these texts is two-fold: on the one hand, they are used to semi-automatically generate the ontology (for details see below). As certain restrictions apply when developing the ontology, it was necessary to write texts specifically prepared for this purpose (see also Haarmann et al. 2012). On the other hand, the texts were also intended to enable users of the system to quickly gain a basic understanding of domain-specific topics.

General guidelines were applied to ensure that the texts were well suited for both purposes and to harmonize them across nearly fifty contributing authors. These guidelines define a common structure for the texts. At the very beginning, the text should start with a general definition (example: electric motor: means to convert electrical to mechanical energy). Then it should proceed, where applicable, with relevant components (motor: e.g. stator

1. BSCW: Basic Support for Cooperative Works (BSCW), http://www.bscw.de/english/index.html.

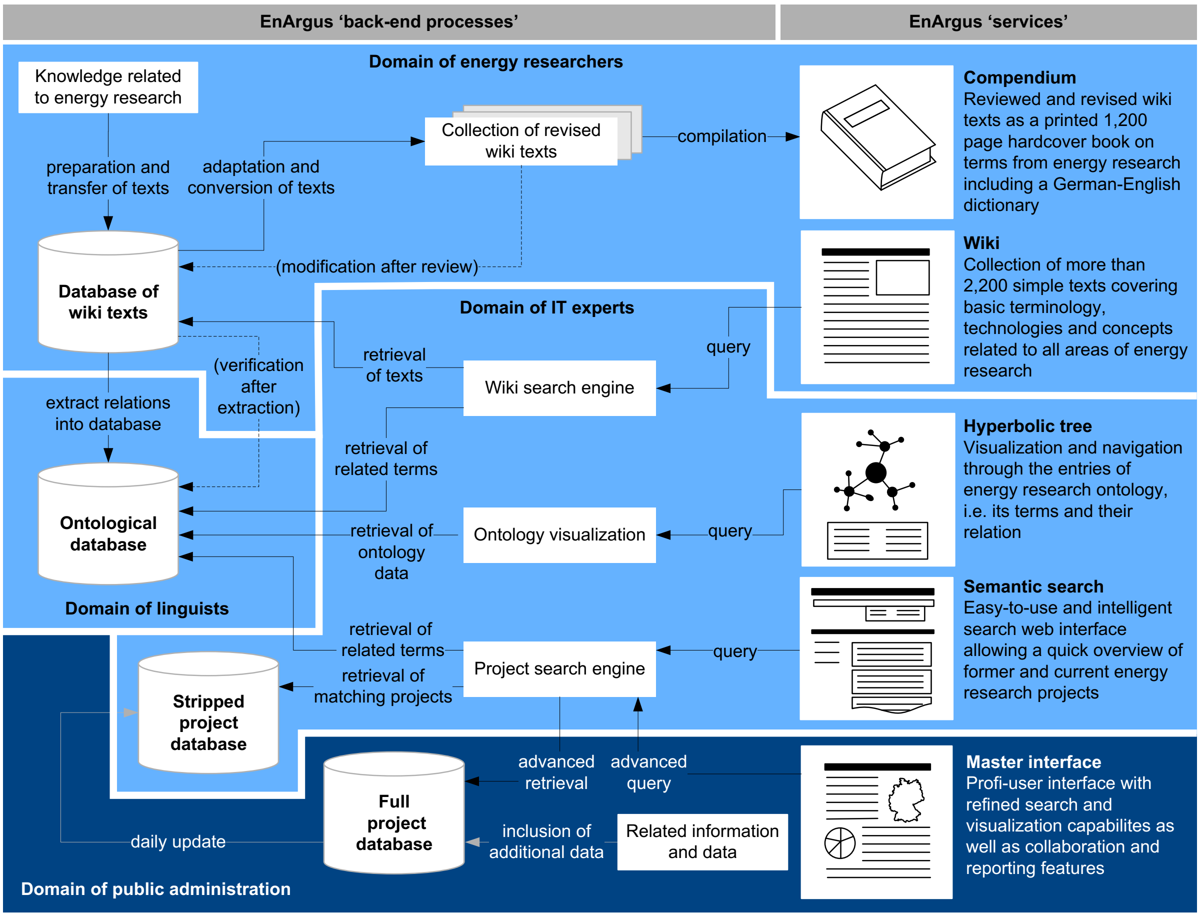



*Figure 2. Simplified overview of EnArgus (light colour: EnArgus.public, dark colour: EnArgus.master).*

and rotor), operating principles (motor: magnetic induction), an overview of types or versions (motor: e.g. AC and DC, synchronous and asynchronous) and information on practical usage or implementation (motor: e.g. pumps, conveyors, compressors). In addition, these texts were to contain English translations as well as synonyms of the title. This made it possible to develop a broad list of synonyms and include English terms in the system. Furthermore, like in other web-based applications, the online versions of the texts are cross-linked to facilitate the navigation of human users to related texts and topics.

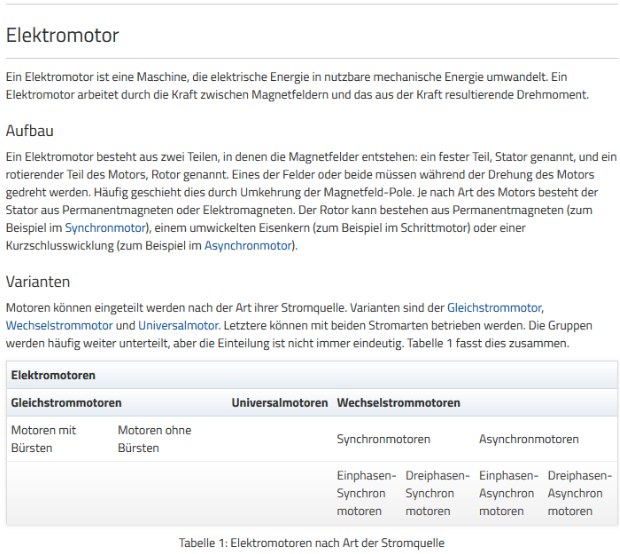
The wiki texts serve as a basis for the EnArgus compendium. This is a hard copy collection of revised and edited wiki texts with about 1,200 pages. Though the wiki texts were written in natural language, they often reflect the requirements of automated text processing, e.g. short sentences, simple grammar and specific style. The wiki texts were revised, reviewed and transferred to a print-ready format to make the knowledge more accessible and available to the 'offline world'. During this review, additional explanations for human readers were included in some cases and a limited list of 'further reading' as well as additional illustrations were added to numerous texts. These changes were partially re-iterated back to the wiki texts after the text processing for the ontology as well.

## ONTOLOGY & HYPERBOLIC TREE

In the context of EnArgus, the ontology is a means to facilitate searching by providing the user with keyword suggestions. In simple terms, it is a formal representation of knowledge, consisting of information about terms from energy research and their relations. Automated text mining facilitates the ontology building process as manually developing domain-specific ontologies is time-consuming and tedious. This process consists of an information extraction step that identifies the individual parts of sentences in a wiki text and a transfer step that translates the information into an ontological data file. In EnArgus, the ontology editor Protégé[2] was used for this purpose (for details, see Haarmann et al. 2012; Sikorski et al. 2015). Within the extraction process, synonyms (alternative terms), hypernyms (superclasses), hyponyms (subclasses) and other information were collected. Synonyms allow suggestions of 'different words' for the search term, hyponyms and hypernyms help to identify 'parts', 'subtypes' or 'families' related to the search terms. The information stored in the ontology can then be used for adding appropriate keys to queries (Figure 4). For example, searching for 'motor' will retrieve 'engine' as a synonym, 'drive system' as a hypernym and 'electric motor' as a hyponym (for details, see Ohrem et al. 2013). At the time of writing, the domain-specific ontology of EnArgus contains approximately 3,900 terms, 7,200 synonyms and 5,100 relations. Query results can be presented as lists (Figure 3b) and visualized as diagrams and geographical maps (Figure 3c).

The hyperbolic tree is a way of visualizing an ontology that facilitates its understanding and review (Figure 3d). Its middle

2. http://protege.stanford.edu/.



Elektromotor

Ein Elektromotor ist eine Maschine, die elektrische Energie in nutzbare mechanische Energie umwandelt. Ein Elektromotor arbeitet durch die Kraft zwischen Magnetfeldern und das aus der Kraft resultierende Drehmoment.

Aufbau

Ein Elektromotor besteht aus zwei Teilen, in denen die Magnetfelder entstehen: ein fester Teil, Stator genannt, und ein rotierender Teil des Motors, Rotor genannt. Eines der Felder oder beide müssen während der Drehung des Motors gedreht werden. Häufig geschieht dies durch Umkehrung der Magnetfeld-Pole. Je nach Art des Motors besteht der Stator aus Permanentmagneten oder Elektromagneten. Der Rotor kann bestehen aus Permanentmagneten (zum Beispiel im Synchronmotor), einem umwickelten Eisenkern (zum Beispiel im Schrittmotor) oder einer Kurzschlusswicklung (zum Beispiel im Asynchronmotor).

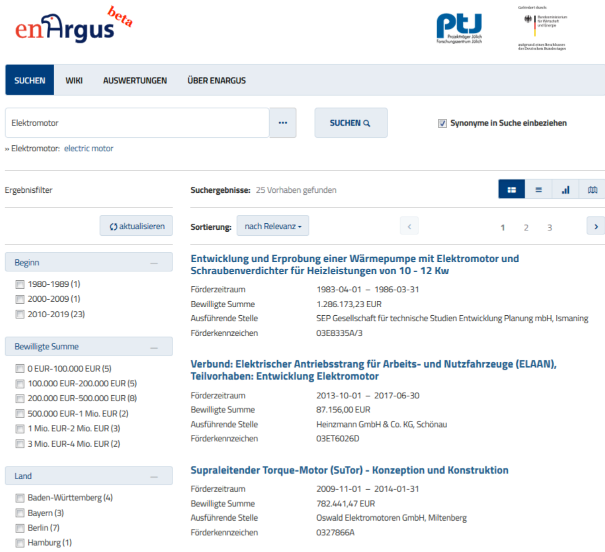
Varianten

Motoren können eingeteilt werden nach der Art ihrer Stromquelle. Varianten sind der Gleichstrommotor, Wechselstrommotor und Universalmotor. Letztere können mit beiden Stromarten betrieben werden. Die Gruppen werden häufig weiter unterteilt, aber die Einteilung ist nicht immer eindeutig. Tabelle 1 fasst dies zusammen.

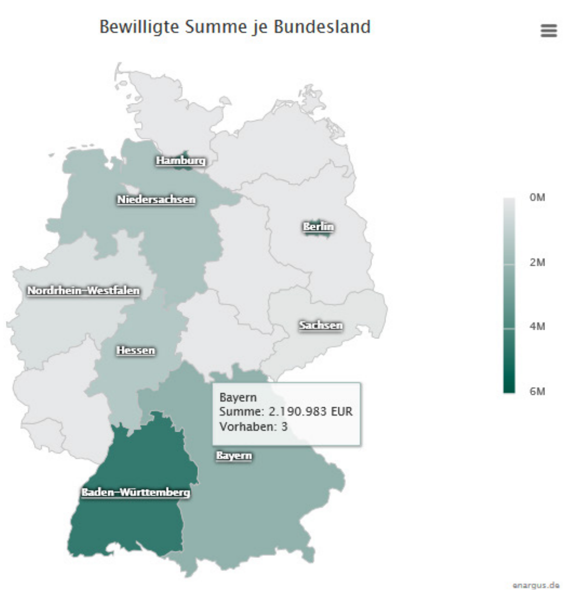
| Elektromotoren | | | | | | |
|---|---|---|---|---|---|---|
| Gleichstrommotoren | | Universalmotoren | Wechselstrommotoren | | | |
| Motoren mit Bürsten | Motoren ohne Bürsten | | Synchronmotoren | | Asynchronmotoren | |
| | | | Einphasen-Synchron motoren | Dreiphasen-Synchron motoren | Einphasen-Asynchron motoren | Dreiphasen-Asynchron motoren |

Tabelle 1: Elektromotoren nach Art der Stromquelle

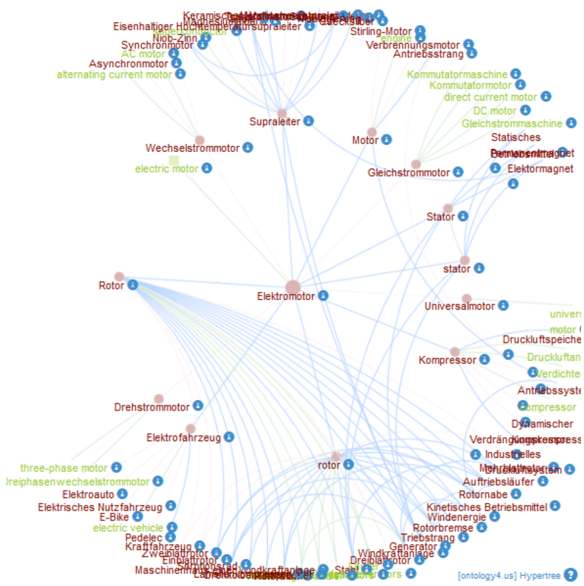
a) Sample wiki text on 'electric motor'.




b) Semantic search results for 'electric motors'.




c) Visualization of funding data for 'electric motors'.




d) Hyperbolic tree for the term 'electric motor'.

*Figure 3. Sample screenshots of EnArgus.public.*

features the starting term as the root node of the tree. Related terms are depicted as branches to this root as additional nodes. These terms are again linked to other terms, and so forth. Within the tree, the user can select the level of depth and navigate through the ontology by clicking on the different terms and – where available – access related wiki entries. On the one hand, this approach allows a user to explore the terms and relations stored in the EnArgus database. On the other hand, this type of visualization is designed as an aid for the participating energy researchers when verifying the draft ontology (Bense et al. 2014; Schade et al. 2015).

The underlying EnArgus.public database is stripped of confidential data from the full project administration database. As it is automatically updated on a daily basis, it always contains the most recent data. At the time of writing (January 2017), it contained more than 44,000 entries. For historical reasons, this number also includes various small funding projects for end-users. At present, the data mainly cover the funding activities of the German Federal Ministry for Economic Affairs and Energy, which is responsible for applied energy research funding in Germany. To enhance the search results in terms of content, additional data were included in the project database during the EnArgus project. These include, for example, additional project descriptions which were not part of the administrative databases and direct links to final project reports published by the German National Library of Science and Technology.

### ENARGUS.MASTER

EnArgus.master extends the functionality of EnArgus.public. This is a system for proficient users, usually operated by public administrators. In terms of data access, the master interface permits full access to project data including confidential information such as personal contact details. Furthermore, the system allows more refined search queries and can save and administrate them. The system also provides more advanced and flexible visualization features and includes groupware features like preparing common reports on energy research for the EnArgus website.

## Evaluation & lessons-learnt

Experiences gained while developing the EnArgus system and from an evaluation process provide valuable insights into the system. These insights can serve as the basis to develop and deploy similar systems for other national or international databases concerning energy research.

### EVALUATION OF THE SYSTEM

As outlined earlier, there were several expectations concerning the practical value of the EnArgus system. Both an internal and an external evaluation process were therefore planned from the outset. The internal process was carried out by the project team members. It included: a) preparing use cases to test the system, b) a structured review of meeting the initial requirements, c) a review of the wiki's coverage, d) a verification of the ontology and e) automated system tests. The external evaluation was based on three workshops with a) university students (not necessarily specialized in energy research), b) energy researchers (from an accompanying research project) and c) members of the public administration. In the following, we focus on the external evaluation process.

In the first workshop, the students from various disciplines were given a brief introduction to the system. Thereafter, they had to carry out a test with different tasks on their own. On average, the students were able to solve 78.9 % of the tasks correctly and only struggled with tasks that required them to find and use the map and diagram view options. Upon completion of this test, they had to fill in an evaluation form containing 33 questions covering the system in general, the wiki texts, the hyperbolic tree and the software interface. On a five-point scale (1-5), the students gave the highest rating (5) to the system in general, the wiki texts and the software interface. Only the hyperbolic tree view was rated slightly less positively (4). The students commented that, while the wiki texts were of considerable use to gain insights into unfamiliar topics, they considered the hyperbolic tree less helpful. Other comments suggested including a manual for the hyperbolic tree and improving the visibility of the button for the map and diagram options on the interface. Overall, however, we can conclude that the participants were able to handle the system quite well and that they evaluated the system very positively.

In the second workshop, researchers from an accompanying research project were given a longer introduction including the master system as well. Thereafter, they were presented with the same test evaluating EnArgus.public. In a second part, they had the opportunity to explore the entire system (both public and master) with regard to specific tasks from the research activities. Here, we only look at the results for EnArgus.public. Similar to the results of the first workshop, the participants were able to solve an average of 80.7 % of the tasks correctly. But, as expected, the participants were slightly more critical of the system. In the evaluation form, the wiki texts were again rated the highest (5)

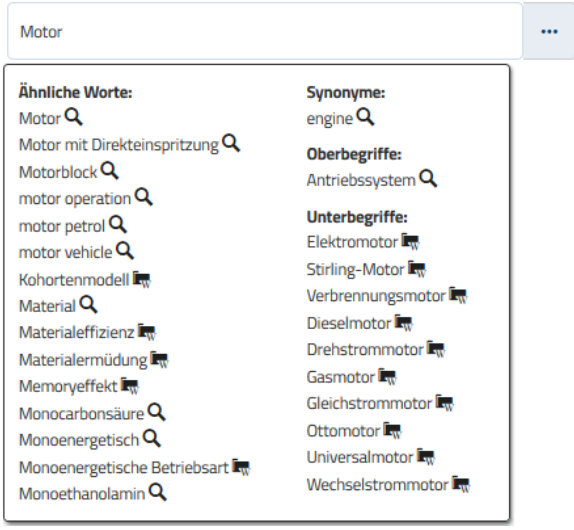



*Figure 4. EnArgus search window for 'motor' showing similar words, synonyms, hypernyms and hyponyms.*

on a five-point scale, while the hyperbolic tree and the system in general were rated slightly lower (4). A likely explanation is that the researchers had certain expectations with regard to fulfilling their tasks whereas the students had none. In addition, they pointed out that some elements of the system like the wiki are less relevant for them, given their expertise in the field. Instead, they asked for more specific data analysis tools. Overall, however, they still gave a positive evaluation of the system.

The third workshop had not yet been held when this paper was written.

The preliminary evaluation results indicate that simple-to-use systems such as EnArgus.public can help non-experts gain insights into energy research activities. Yet such simple systems evidently also have limitations in terms of flexibility, as their simplicity requires pre-structuring the required and presented information. EnArgus.master provides a more flexible and comprehensive tool but it is evidently more difficult to use. Furthermore, there is no one-size-fits-all solution for such systems and not all the elements of the system are equally important to all target groups. While non-experts, for example, greatly appreciate the wiki texts, expert researchers naturally only benefit from them to a more limited degree. The visualization of the ontology, as another example, seems especially helpful for those users who want to understand the background and methodology in detail.

Using the ontology-assisted search engine as the methodological core considerably facilitates the navigation through energy research funding activities but it should be noted that this system also has restrictions. From a content-oriented perspective on energy research, there are many different ways to structure knowledge, and consequently, there is no unique way to set up an ontology. So the core issue is to establish a 'helpful' system rather than striving for a subjectively 'well structured' one. The evaluation seems to indicate that 'helpfulness' has been achieved in the project.

### LESSONS LEARNT

In addition to the specific results from the evaluation process, more general lessons learnt can also be derived. These concern both the transfer of energy-related knowledge to the system as well as socio-technological challenges related to its design.

From a content point of view, it became evident that it is challenging to translate expert knowledge into simple texts for automated text processing and for a general audience at the same time. This is especially true when clear, simple and generally agreed definitions are not available. Furthermore, preparing a large number of texts as in this project requires careful planning. It is not easy to define such a consistent set of short texts at an early stage of writing: On the one hand, experience shows that it often only becomes clear at the time of writing what terms are actually required in detail. On the other hand, similar concepts from neighbouring areas of expertise or concepts discussed on different levels of aggregation can easily lead to overlaps that are difficult to spot.

From a socio-technical perspective, recent developments of popular websites also seem to have had a considerable impact on the perception of such information systems as EnArgus. First, users generally expect a quite simple, intuitively usable and appealingly modern implementation. Furthermore, they expect similar features to those in popular search engines, including search suggestions, a certain level of tolerance with regard to spelling mistakes and quick delivery of results. At the same time, a visualization of the results is also important. Finally, a critical success factor for the development and deployment of information systems like EnArgus is that experts from different disciplines cooperate closely and that the public administration is also closely involved in this process. It is important to consider these aspects if modern information systems are to be successfully implemented and deployed.

## Conclusions

In this contribution, we briefly illustrated how energy research funding can be made more transparent and accessible using the example of the centralized German energy research system ‘EnArgus’. Such modern information systems on energy research make it easier to answer questions like “What’s going on in energy efficiency research?”. EnArgus with its combination of domain-specific texts, ontological knowledge base and modern web interface appears well suited to the task of keeping up with the ever-growing number of projects related to energy research. The results from its evaluation are quite encouraging and support the idea of transferring this concept to similar systems, e.g. other national or international databases related to energy research.

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