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Comparing Ontologies in Energy Research

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1 Introduction

Research data and software play an integral part to enable research and make collaboration possible [1]. As such there is a need to produce digital research objects like research data and research software as open as possible [2]. Wilkinson, Dumontier, Aalbersberg, *et al.* [3] developed the FAIR principles to aid in the handling and reuse of digital research objects. These principles were extended by Hasselbring, Carr, Hettrick, *et al.* [4] to research software. Interoperability is a key element to enable FAIR research. Ontologies, a concept out of the semantic web, enable interoperability. There are however many ontologies in the energy research field and it is often not clear, which one is best suited for use. In our presentation we want to show which ontology are useful within the energy domain by comparing them.

2 Methodology

There are three steps taken to enable the comparison of ontologies in energy research. First relevant ontologies are identified through a literature review using a modified PRISMA approach [5]. After this criteria for the comparison are compiled. The criteria are based on ontology engineering literature, such as Arp, Smith, and Spear [6], and metadata like the license of the ontology. Furthermore, a score is calculated based on the criteria. In the last step the ontologies are compared based on the compiled criteria and scores.

3 Results

This section shows the results of the methodology described in section 2.

3.1 Literature review

The literature review based on PRISMA consists of four phases. The phases filter ontologies that are not written in english, do not fit the topic an are not relevant[1]. Furthermore, only openly accessible ontologies are eligible. At the end at most one ontology

[1] Relevancy is defined as being either new, cited a lot or a standard

of a specific energy subdomain is selected, e.g. smart homes. The eight selected ontologies for the comparison can be found in table 1.

Table 1: Ontologies identified for comparison. Citations taken from Google Scholar. Citations last checked: 08.02.2023. Sorted alphanumerical by ontology name.

Ontology	**Topic**	**Year**	**Reference**	**Standard**	**Citations**	**Gov. Funding**
Brick	Smart home	2016	[7]	✗	264	✓
CIM	Energy domain	2003	[8]	✓	3	✓
Dabgeo	Energy domain	2020	[9]	✗	14	✓
EMO	Energy Markets	2016	[10]	✗	22	✓
EM-KPI	Smart Grid	2019	[11]	✗	32	✓
OEO	Energy domain	2021	[12]	✗	30	✓
Sargon	Energy domain	2020	[13]	✗	17	✓
SEAS	Energy domain	2017	[14]	✗	78	✓

3.2 Criteria and Score

The selected criteria are divided into four categories and get well defined to avoid confusion. The criteria in their categories are shown in table 2

Table 2: The 21 ontology criteria divided into the 4 categories.

Category	**Criteria**
Best Practice	Used Upper Ontologies, Scope, Creation Type, Modularity, Extensibility, Validation
Practical Implementation	Available Languages, Available Ontology Languages, Description Size, Description Quality, Number of Terms, Used Ontologies
Maintenance & Accessibility	Sourcecode, License, Accesibility, Maintenance, Latest Release, Automatic Analysis
Governance	Funding, Governing Instances, Citations

An example of the criteria definition and its scoring is shown below based on the license criterion:

License

This criterion defines the license of the ontology it is divided into two categories:

Not Found: Ontology license not found. (Score: 0)
License Found: Ontology license found. (Score: 3)

The score is compiled using the following formula:

$$F = \frac{1}{n} \cdot \sum_{i=1}^{n} a_i,$$

where $a_i \in [0, 3]$ is the score given for a criteria, n is the number of quantified criteria, and $F \in [0, 3]$, is the score per category.

3.3 Comparison

Some general findings are, that most ontologies did not use an upper ontology as their base. Furthermore, the validation method used on the ontologies differs greatly and is not consistent between ontologies. Five of the ontologies are no longer maintained actively. During the automatic analysis for this comparison all of the ontologies show problems in their implementation. The computed score is shown in table 3 The four best scoring ontologies are the Open Energy Ontology(OEO), BRICK, SEAS and CIM. The OEO is the best scoring with an accumulated score of 10.2. For all categories except governance it also has the highest individual score.

Table 3: Accumulated scores for each ontology.

Accumulated Score	Best Practice	Practical Implementation	Maintenance and Accessibility	Governance	Ontology
10.2	2.8	3.0	2.4	2.0	OEO
9.6	2.2	2.0	2.4	3.0	Brick
9.6	1.8	3.0	1.8	3.0	SEAS
9.4	2.0	2.0	2.4	3.0	CIM
7.7	1.6	3.0	1.6	1.5	EM-KPI
6.4	2.2	2.3	1.6	0.3	Sargon
6.3	2.2	2.3	1.4	0.3	Dabgeo
6.0	1.0	2.7	0.8	1.5	EMO

3.4 Conclusions

Ontologies are an important foundation for research data management and as such are a useful tool to aid researchers. As there are many ontologies to choose from it is important to compare the existing ontologies to make selection easier. All of the ontologies looked at are compared in 21 criteria categorized into four categories. A score is developed to aid researchers in comparing. The highest scoring comparison is the Open Energy Ontology. However while the ontology is the highest scoring it still has some flaws that can be addressed.

Author contributions

Alexandro Steinert: Conceptualization, Methodology, Writing- Original draft preparation, Writing- Reviewing and Editing, Investigation. Stephan Ferenz: Conceptualization, Writing- Reviewing and Editing, Investigation. Astrid Nieße: Supervision, Funding acquisition.

Competing interests

The authors declare that they have no competing interests.

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