POLAND'S ENERGY TRANSITION: TOWARDS AN ONTOLOGY

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Piotr Glenc

Introduction

Numerous countries around the world are currently facing challenges associated with the energy transition. It entails a shift away from using non-renewable resources in the energy mix, towards a system primarily based on renewable as well as zero and low-emission energy sources (Młynarski, 2019). According to the European Green Deal, EU member states should achieve net zero greenhouse gas emissions by 2050, and as such they are particularly determined to engage in the transition process (Vieira et al., 2021). Energy transition is a challenge not only for national governments, but also for many other organisations which need to implement changes across different areas of their operations (for example see Asmelash, Gorini, 2021). The thorough knowledge of the transition process is a must to successfully plan and implement these changes.

Understanding the energy transition process means more than just considering it in the backdrop of new energy

technologies. Environmental, economic and management related concerns also have to be taken into account (Chen et al., 2019). From the point of view of numerous parties (such as international institutions, local government units, energy sector enterprises and households), such a complex reality requires domain knowledge to be organised and presented in a synthesised form. An ontology is another way to represent domain knowledge. Ontology is a formal and ordered definition of the key concepts and their interrelationships (cf. Niedbał, 2014). Energy related ontologies have already appeared in the scientific literature (for example see Booshehri et al., 2021; Cuenca et al., 2020; Küçük, Arslan, 2014). However, no ontology for Poland's energy transition has been developed to date. It would certainly facilitate the ordering of domain terminology. Such an ontology could also be a component of smart systems and tools used in organisations associated with the energy transition process. This would establish a common terminology layer and facilitate data exchange between different systems. Examples include tools that process transition related text documents, expert systems, information retrieval systems and decision support systems.

Building an ontology requires an in-depth analysis of the modelled fragment of the real world. One can identify a number of useful sources for acquiring knowledge about the energy transition. Relevant issues are examined in the scientific literature, in the media and during expert panel discussions, for example. Parliamentary debates are also a valuable source of the knowledge on the energy transition, as they present different perspectives on the issue. The opportunities and challenges brought about by the energy transition process are seen in a different light by the various sides of the political dispute. They have different visions as to how the process should proceed. Ultimately, parliamentary debates shape the legal regulations that are or are to be implemented in the energy transition process.

The aim of the research described in this paper was to construct an ontology for the energy transition in Poland, containing at least a class hierarchy and sample instances. Transcripts of discussions about the energy transition in the Polish parliament, kept within the Polish Parliamentary Corpus (PPC) (Ogrodniczuk, 2018) were used as a source of knowledge needed in the process of building the ontology. Specialised terminology was then extracted automatically from the created corpora using the TermoPL tool (Marciniak et al., 2016). The analyses of the obtained results were then used as a basis for constructing Poland's energy transition ontology, containing classes and sample instances as well as some data properties. The ontology has been constructed in OWL using the Protégé editor and made publicly available online. Recommendations have been formulated regarding the use of the developed ontology in organisations.

The theoretical background related to the creation of ontologies and analysis of parliamentary debate transcripts is presented in the next part of this paper. Various stages involved in the investigation performed within the scope of the research in question are described in the following section. Then come the obtained results, the description of the developed ontology and recommendations for its use in organisations. The last section of this article contains a summary and a discussion of the results. It also sheds some light on directions for future research in the subject.

Theoretical basis

Ontologies — definition, utilization and the development process

According to the classical definition put forth by Gruber (1993), an ontology is „an explicit specification of a conceptualization". Ontologies represent objects, concepts and their mutual relations in a specific domain, in formats adapted for computer processing such as RDF/OWL (Merah, Kenaza, 2021). Such a manner for modelling certain parts of reality introduces shareable and reusable knowledge representation and can add new knowledge about a domain (Goldstein et al., 2021). When it comes to management, ontologies are most often described from the knowledge management perspective, as they constitute a certain way of representing knowledge (for example see Niedbał, 2014). To date numerous ontologies have been unveiled in the scientific literature for areas such as cyber risk (Merah, Kenaza, 2021), higher education (Tapia-Leon et al., 2018), sustainable development (Ivanova et al., 2021), nutrition (Castellano-Escuder et al., 2020) and real estate (Hammar et al., 2019). The issue of building an ontology for the energy sector has already been approached (for example see Booshehri et al., 2021; Cuenca et al., 2020; Küçük, Arslan, 2014). However, there is no ontology for the energy transition process in Poland.

Representing knowledge in the form of an ontology can be useful for an organisation. Ontologies can be incorporated into IT tools used in organisations, such as decision support systems (cf. Jean-Baptiste, 2021, pp. 179–184) or text document processing tools (cf. Sanchez-Pi et al., 2016). The implementation of the ontological model makes it possible to define unambiguous terminology and thus reduces the risk of misunderstandings in the communication processes. It also provides shared understanding of the domain knowledge within the organisation (Filipczyk, Gołuchowski, 2006). Ontologies also facilitate the integration of data from multiple heterogeneous sources (García et al., 2016). The utility of ontologies in designing information architecture, e.g. in corporate portals, has also been noticed (for example see Billewicz, 2011).

According to the method proposed by Noy and McGuiness (2001), the process of building an ontology entails the following steps: (1) determine the domain and scope of the ontology, (2) reuse existing ontologies, (3) enumerate the most important domain terms, (4) define classes and class hierarchy, (5) define data properties (slots), (6) define facets for the created slots (e.g. data types and allowed values), (7) create class instances. The basic approach to ontology building involves experts in the process (Wang et al., 2019). Furthermore, resources such as natural language texts, HTML documents, relational databases and other existing ontologies may be

useful for building ontologies (Lakzaei, Shmasfard, 2021). There is a widespread interest among researchers in the use of texts in the process of constructing ontologies. Abramowicz and Wiśniewski (2008), Confort et al. (2015) as well as Wang et al. (2019) are amongst those who have described such approaches.

Specialised IT tools may be used to define terminology relevant to the domain modelled in the ontology. TermoPL is one such tool for extracting specialist terminology from Polish texts (https://ws.clarin-pl.eu/termopl.shtml). On the basis of the processed corpora of texts, the tool generates a ranking of noun phrases, with the most relevant ones for the domain in question displayed at the top. The tool uses the C-value measure to rank phrases. It takes into account the number of times a given phrase appears in a text, its length and the number of contexts in which the phrase appears (Marciniak et al., 2016). The C-value for individual phrases is calculated according to the following formula:

$$C-value(p)=\begin{cases} l(p)*(freq(p)-\frac{1}{r(LP)}\sum_{lp\in LP}freq(p)) & r(LP)>0 \\ l(p)*freq(p), & r(LP)=0 \end{cases}$$

where:

p – phrase in question,
$l(p)$ – log of the phrase length or a constant value (e.g., 0.1) for single words,
LP – set of other phrases containing p,
$r(LP)$ – number of phrases in LP.

TermoPL developers state that the tool can be useful for building domain ontologies (Marciniak et al., 2017). Utilisation of the tool for this purpose has been described in this paper.

Analysis of parliamentary debate transcripts

Analysis of the Polish parliamentary debate has already been the subject of many studies, and the results have proved useful in the fields of linguistics (Przyklenk, 2020) and political science (Wójcik, 2015), among others. It should be pointed out that from a cognitive point of view such an analysis can also be relevant for management sciences as a way to monitor the legal environment of an organisation.

An effective analysis of parliamentary debates is possible thanks to specially developed corpora, which primarily constitute a repository of parliamentarians' speeches and often have additional features that facilitate their use (e.g., linguistic annotation, metadata). Corpora containing statements by parliamentarians in the Norwegian (Lapponi et al., 2018), Czech (Jakubícek, Kovár, 2010), German (Blätte, Blessing, 2018) and Icelandic (Steingrímsson et al., 2020) parliaments have been developed so far. Polish parliamentary debate transcripts are kept in the Polish Parliamentary Corpus (https://kdp.nlp.ipipan.waw.pl/). This corpus contains transcripts of Polish Parliament sessions from 1919 to the present day, including transcripts of the plenary sittings of the Sejm and the Senate (the two chambers of the Polish Parliament), parliamentary enquiries and questions as well as minutes of committees' meetings. This data is updated on an on-going basis (Ogrodniczuk, 2018; Ogrodniczuk, Nitoń, 2020). PPC resources have been processed using linguistic tools and populated with metadata, which facilitates their use and provides a wide range of possibilities for their application in various types of analyses and research. Thus far, PPC has not been used to find and analyse statements pertaining to the energy transition.

Research method

There were 5 stages to the procedure used for the research described herein:

- acquisition of research material in the form of a collection of statements pertaining to the energy transition that have appeared in the Polish parliamentary discourse (from PPC),
- automatic analysis of the acquired data using the TermoPL tool to obtain a compilation of specialised terms, relevant in the field of energy transition,
- analysis of results generated by TermoPL and use thereof to construct an ontology,
- formulation of sample SPARQL queries for the created ontology,
- formulation of recommendations for the use of the developed ontology in organisations.

A segment search engine in the PPC was used to retrieve the research material. A search was made for all statements containing the phrase „transformacja energetyczna" (energy transition) and its inflectional forms[1]. These statements were then saved as .txt files. It was assumed that entire statements would be included in the data set, even if they did not exclusively address the energy transition issue. This set of statements was then processed by the TermoPL tool, and a list of key phrases was generated. All terms were analysed, and an ontology was developed in OWL using the Protégé editor on the basis thereof.

Research results

Energy transition in Polish parliamentary discourse

Statements in the Polish Parliamentary Corpus contained 384 hits for the phrase „transformacja energetyczna" (energy transition) and its other inflected forms (as at 17 September 2021). The phrase was used for the first time in 2008, however it did not appear in a statement by a Polish politician, but in a quote taken from by Nathalie Kosciusko-Morizet, at the time engaged with French politics. The term appeared in the vocabulary of Polish politicians in 2013, with a noticeable increase in the number of statements on the subject in and after 2019. Thus, we are able to claim that since that time the energy transition in Poland is no longer a kind of vague vision or concept of the future, but has become a real challenge discussed in parliamentary debates. Figure 1 depicts the number of times the „transformacja energetyczna" (energy transition) phrase appeared in parliamentary discourse between 2008 and 2021 (up to 17 September 2021) based on data from the Polish Parliamentary Corpus.

The search results comprised 274 statements containing a total of 384 hits for the „transformacja energetyczna" (energy transition) phrase. This set was then analysed using the TermoPL tool. Table 1 shows an extract of the ranking obtained for the first 10 (most relevant) phrases.

The ranking generated by TermoPL tool took into account a total of 901 phrases. „Unia Europejska" (European Union) was found to be the most significant phrase, indicating that Polish parliamentarians repeatedly referred to the European Union in various contexts in their speeches, probably pointing to EU bodies as the main proponents of the energy transition idea.

Developed ontology

The phrases that appeared in the ranking generated by TermoPL were subsequently analysed and used to identify the concepts that should be included in the ontology under construction. It is worth noting that some phrases in the ranking directly referenced potential classes (e.g., „odnawialne źródło energii" (renewable energy source), „państwo członkowskie" (Member State), „spółka Skarbu Państwa" (national company)) or instances (e.g., „Komisja Europejska" (European Commission), „Polska" (Poland), „węgiel kamienny" (hard coal)). Some elements of the constructed ontology were not directly derived from the phrases indicated by TermoPL, but rather were inferred from them. For example, occurrence of the phrases „województwo" (voivodeship), „Śląsk" (Silesia) or „Europa Środkowa" (Central Europe) was considered a premise for the creation of the „Territory" class within the ontology, even though such a term did not appear at all in the ranking generated by TermoPL. Similarly, the „Renewable Energy Source" class was considered to justify the creation of the „Non-Renewable Energy Source" class, even though this was not explicitly apparent from the results generated by TermoPL. Some phrases were considered identical and were added to the ontology as one class (e.g., „kraj członkowski" (member state) and „kraj Unii Europejskiej" (European Union state)). It should also be noted that some terms not pertaining to the energy transition but related for example to the language of parliamentary debate (e.g., „szanowni państwo" (ladies and gentlemen), „wysoka izba" (honourable members), „pan poseł" (deputy)), were identified as relevant by TermoPL tool. These terms were not included in the ontology.

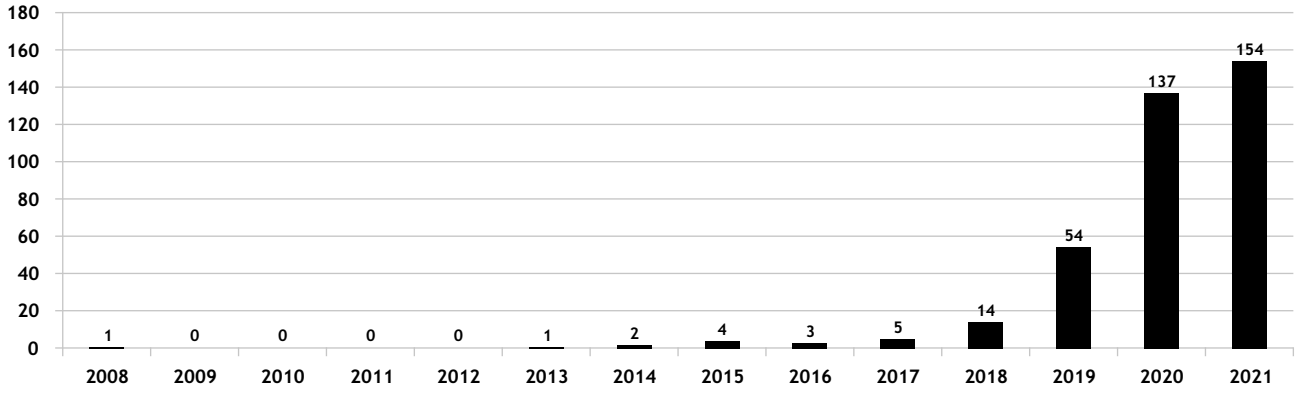

Figure 1. „Transformacja energetyczna" (energy transition) phrase in the Polish Parliamentary Corpus (up to 17 September 2021)
Source: in-house materials based on Polish Parliamentary Corpus data

Table 1. Fragment of the phrase ranking list generated by TermoPL

Ranking	Phrase (PL)	Phrase (EN)	C-value
1	Unia Europejska	European Union	3.9e+2
2	transformacja energetyczna	energy transition	3.5e+2
3	sprawiedliwa transformacja	just transition	2.7e+2
4	Komisja Europejska	European Commission	2.2e+2
5	Szanowni Państwo	Ladies and Gentlemen	1.7e+2
6	Krajowy Plan Odbudowy	National Recovery Plan	1.6e+2
7	Państwo członkowskie	member state	1.6e+2
8	Krajowy Plan	National Plan	1.5e+2
9	energia elektryczna	electrical energy	1.5e+2
10	odnawialne źródło energii	renewable energy source	1.3e+2

Source: in-house materials based on results generated by TermoPL tool

The resulting ontology comprises 90 classes, 119 instances and 11 data properties. Figure 2. shows a fragment of class hierarchy (in Polish and English) comprising part of the ontology.

It should be pointed out that the classes in the created hierarchy are not defined as disjoint, which means that an instance can belong to more than one class.

The ontology has been published in both languages: https://github.com/piotrglenc/energytransitionontology. The current version of the ontology should be considered to be a prototype, with many alterations still needed. Of particular note is the fact that the ontology contains no object properties responsible for specifying links between the concepts.

SPARQL queries

Despite some limitations, the ontology can already be considered a useful resource for the knowledge on subjects related to the energy transition. Table 2 depicts the examples of SPARQL queries used to extract certain data from the ontology, together with the results thereof. Table 3 shows the examples of queries that cannot be applied to the ontology for the time being, but potentially might be once the ontology is appropriately expanded.

It is worth noting that the potential applications for the ontology are not limited to data extraction using SPARQL queries. Using semantic reasoners, it is possible to uncover knowledge not explicitly saved in the ontology. Furthermore, as indicated in the introduction, an ontology can serve as a component of various IT systems used in organisations.

Recommendations for organisations

The developed ontology can be used in various areas of organisations' activity. The following recommendations have been formulated:

- The ontology defines domain vocabulary, therefore it can be used to ensure a consistent conceptual layer between various tools used in organisations (e.g. databases, websites), especially in companies in the energy industry.
- Systems that automatically process text documents on energy transition can be enriched with ontology knowledge. Examples include automatic text summarisation systems.
- The proposed ontology can be used in the process of data integration, both from internal and external sources containing data related to the energy transition process. An interesting perspective in this regard is the acquisition of data from various types of websites (e.g., industry portals related to energy, websites of energy industry companies, news on government websites). This will allow organisations to monitor current activities related to the energy transition.

Figure 2. Class hierarchy fragment for the ontology in two corresponding language versions
Source: in-house materials developed using Protégé

- As the ontology was built based on parliamentary statements, it can also be useful for political organisations (e.g., parties) as a summary of the Polish parliamentary debate, which makes it possible to identify key issues and challenges related to the energy transition.

Discussion and conclusion

This article puts forward an ontology for Poland's energy transition. An automatic analysis of the statements by Polish parliamentarians that related to the issue of energy transition was carried out within the scope of constructing this ontology. This means that the ontology can also be seen as a kind of summary of parliamentary debates. Analysing then the occurrence of the „transformacja energetyczna" (energy transition) phrase in parliamentarians' statements over subsequent years has shown that the issue is current and has been discussed much more frequently in the last few years than before. The article also presents an example of using the Polish Parliamentary Corpus and the TermoPL tool in the process of building a domain ontology. These resources have not been used for this purpose to date. Making the ontology publicly available in two language versions provides ample opportunity for expansion, further use and evaluation.

Table 2. Examples of SPARQL queries for the ontology

Prefixes used in queries	PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> PREFIX et: <http://www.semanticweb.org/EnergyTransitionInPoland#>	
Query objective	**SPARQL query**	**Result**
Show all types of power plants	SELECT ?typeOfPowerPlant WHERE { ?typeOfPowerPlant rdfs:subClassOf et:PowerPlant}	typeOfPowerPlant WindPowerPlant NuclearPowerPlant CoalPowerPlant GasPowerPlant
Show non-renewable energy sources	SELECT ?source WHERE { ?source a ?type. ?type rdfs:subClassOf* et:NonrenewableEnergySource }	source Petroleum NaturalGas ShaleGas BrownCoal HardCoal
Check whether natural gas is a renewable energy source	ASK WHERE { et:NaturalGas a et:RenewableEnergySource }	Result False

Source: in-house materials

Table 3. Examples of SPARQL queries for the ontology (after expansion)

Prefix used in queries	PREFIX et: <http://www.semanticweb.org/EnergyTransitionInPoland#>
Query objective	**SPARQL query**
Show coal power plants found in the Silesian Voivodeship	SELECT ?powerPlant WHERE { ?powerPlant a et:CoalPowerPlant. ?powerPlant et:Location et:SilesianVoivodeship }
Check if there are any nuclear power plants in Poland	ASK WHERE { ?powerPlant a et:NuclearPowerPlant. ?powerPlant et:Location et:Poland }
Calculate total installed capacity for wind power plants in individual voivodeships	SELECT ?voivodeship (SUM(?capacity) AS ?totalCapacity) WHERE { ?powerPlant a et:WindPowerPlant. ?voivodeship a et:Voivodeship. ?powerPlant et:Location ?voivodeship. ?powerPlant et:InstalledCapacity ?capacity } GROUP BY ?voivodeship

Source: in-house materials

Despite many advantages outlined above, some limitations of the research described in this article should also be mentioned. The first group of limitations is associated with the use of the statements from parliamentary debates as a source to extract domain-specific terminology and the restriction of the search to the „transformacja energetyczna" (energy transition) phrase only. Indeed, many politicians in their speeches instead of „transformacja energetyczna" (energy transition) use similar terms, such as „transformacja energetyki" (energetics' transition) or simply „transformacja" (transition). Such statements were not included in the research unless they simultaneously contained the phrase „transformacja energetyczna" (energy transition). Further limitations are associated with the use of TermoPL for extracting the domain terminology. The fact that the tool recognises only noun phrases as key terms has resulted in a particularly extensive class hierarchy and number of instances in the developed ontology, while object properties (which could be rather identified by analysing verbs in the texts) have not been included. Another limitation stems from the fact that the developed ontology has not been evaluated as there is no reference ontology built by experts, which could be considered as a basis for possible comparison and evaluation. However, it should be pointed out that elimination of the limitations referred to hereinabove would rather lead to an expansion of the proposed ontology but should not result in the elimination of elements that have already been defined.

There is field to continue the research described in this article and to develop and improve the constructed ontology. While identifying directions for future works one feels obliged to mention the need for expert evaluation of the proposed ontology and its expansion in accordance with the recommendations. Expanding the ontology would formalise domain knowledge, but also facilitate the application of semantic reasoners resulting in better knowledge extraction. The constructed ontology can also be a component of the IT tools used in organisations. Further works might also consider repeating the conducted research procedure using parliamentary debates from countries other than Poland. This would make it possible to compare goals, challenges and ideas associated with implementing the energy transition process in different countries.

Piotr Glenc, M.Sc.
University of Economics in Katowice
Faculty of Informatics and Communication
ORCID: 0000-0003-4147-4133
e-mail: piotr.glenc@ue.katowice.pl

Endnote

1) The executed query: [base=„(transformacja)"][base=„(energetyczny)"]

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W kierunku ontologii transformacji energetycznej w Polsce

Streszczenie

W artykule przedstawiono proces tworzenia ontologii transformacji energetycznej w Polsce bazujący na ekstrakcji terminologii dziedzinowej z zapisów debat parlamentarnych. Wypowiedzi dotyczące transformacji energetycznej zebrano, wykorzystując Korpus Dyskursu Parlamentarnego. Następnie zebrany zbiór wypowiedzi przetworzono przy użyciu narzędzia TermoPL służącego do ekstrakcji specjalistycznej terminologii dziedzinowej. Na podstawie uzyskanego zestawienia kluczowych terminów opracowano ontologię OWL w edytorze Protégé. Opracowana ontologia składa się z 90 klas, 119 instancji i 11 własności klas. Ontologia została udostępniona w Internecie w dwóch wersjach językowych (polskiej i angielskiej), dzięki czemu może być poddana ewaluacji, dalszemu rozwojowi lub wykorzystana w specjalistycznych zastosowaniach w organizacjach.

Słowa kluczowe

transformacja energetyczna, ontologia, ekstrakcja terminologii, pozyskiwanie wiedzy z tekstu