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Article

Managing Climate Policy Information Facilitating Knowledge Transfer to Policy Makers

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Abstract: In the challenging context of intense negotiations and radical developments in the field of climate policy, informing stakeholders about opportunities and pathways and about scientific insights and warnings is important to help create positive dynamics. Policy makers need digestible information to design good policies, and understand their options and the possible impacts of these options. They need access to well-structured knowledge, as well as appropriate techniques to manage information and data. However, available information is often difficult to access, not in the right format and of limited use to stakeholders. The range of knowledge needs identified has to be effectively addressed by providing interested parties with suitable, to-the-point information, covering the identified gaps. This is the main aim of this article that proposes the design and development of a climate policy database, which contains all the resources that can cover the identified knowledge gaps. The resources are derived from a broad range of existing reports, research and climate policy decisions at different levels. The goal is to render climate policy associated stakeholders able to extract key policy conclusions. The added value of this database was verified by users and stakeholders that generally argued that the climate policy database facilitates solid understanding of climate policy implications and fosters collaborative knowledge exchange in the field.

Keywords: climate change; international and European climate policy; knowledge transfer; architectural knowledge retrieval; ontology; resource description framework

1. Introduction

The international community has intensified its activity towards a collective response to climate change [1]. The Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC) meeting in December 2015 (COP21) ensures that all parties focus on the long-term goal to keep global mean temperature rise "well below 2 °C and to pursue efforts to limit the temperature increase to 1.5 °C" [2]. The emission reduction pathways needed are ambitious but not impossible as many of the needed technological solutions are known. Mitigating climate change will not only prevent human suffering and protect our biological diversity, but will also be less costly than adapting to the effects of climate change [3].

It is, however, a great challenge in industrialised countries to restructure consumption and production patterns into a low-carbon system [4]. On the other hand, developing countries are concerned that a low carbon pathway could hamper their overriding priorities of economic growth and poverty eradication [5]. Furthermore, the international community has not yet agreed on how to distribute the cost of mitigation efforts and the level of ambition among themselves [6]. It therefore does not come as a surprise that international negotiations are moving slowly and the level of ambition as shown by voluntary international pledges does not suffice to limit global warming below 2 °C.

In the difficult context of intense negotiations and radical developments in the field of climate policy, informing stakeholders about opportunities and pathways and about scientific insights and warnings is important to help creating positive dynamics. Policy makers need digestible information to design good policies, and understand their options and the possible impacts of these options [7]. They need access to improved knowledge transfer and uptake, as well as appropriate techniques to manage information and data [8,9]. However, available information is often difficult to access, not in the right format and of limited use to stakeholders [7,10].

For the European Union (EU), the changed climate negotiations perspective creates several new opportunities, as well as challenges. It is therefore important to coordinate and facilitate the information exchange and outcomes of existing research on climate policy and climate agreements in order to broaden the knowledge in the field and enable associated stakeholders to extract key policy conclusions. In this respect, the first step is to identify knowledge needs among stakeholders, concerning both, knowledge gaps, as well as knowledge presentation requirements. Knowledge gaps can either mean lack of awareness of existing knowledge, or actual absence of scientific analysis regarding an issue.

As a consequence, exchange of information about climate policy and knowledge transfer among stakeholders need to be facilitated in order to offer clear understanding of current regimes, their possible directions, implications and consequences and to render them capable of taking well-informed, consolidated decisions based on up-to-date reliable facts [11–15].

To this end, it is important to assimilate the in-stock knowledge on climate policy issues in a running database, which will be enhanced by relevant projects and discussion outcomes of climate negotiations. The aim of this paper is to present such a Climate Policy Database that serves as an electronic library and contains all the resources that can cover the identified knowledge gaps. The resources are derived from a broad range of existing reports, research and climate policy decisions at different levels. The goal is to render climate policy associated stakeholders better able to extract key policy conclusions. This particular study is oriented towards the presentation of the structuring of a climate policy database for the provision of accurate and easily accessible information.

In particular, this work aims to collect and cluster the existing knowledge on climate policy in an open input dataset, so as to provide the structured content for disseminating this knowledge to support informed decisions and beliefs of the policy makers, researchers, market actors and general public. A hierarchical structure of tags is created, where each tag provides semantic content to the relevant scientific studies and reports that form the resources collected. Since there are a vast number of research studies—with different assumptions and approaches—regarding the dynamics and direction of the new climate regime, a meta-analysis is carried out in order to decompose their results to the assumptions, factors and interactions considered. The outcomes of the decomposition is annotated with the aforementioned structure of tags so that semantic search is possible through a platform.

Apart from this introductory section, the paper is organized along five sections. The second section presents the requirements and functionalities to be met for the implementation of the Climate Policy Database. The third section provides an overview of the methodological approach, offering an analysis of the ontology and its applications. Following, the successive stages and technological choices followed to create the Climate Policy Database are presented. The last section summarizes the main conclusions arisen from the study.

2. Background

Ontologies are clear specifications of formalities [16–18]. In brief, they are explicit depiction of theories, relations between theories (including, but not limited to, a hierarchy), instances, and axioms. The term explicit implies two facts: on the one hand, through the representation individuals could be able to understand the exact meaning of any component, so as to have a precise terminology available when commenting on data, communicating inquiries, or summarising outcomes. On the other hand, the depiction could assist machine reasoning, as it obtains a typical semantics. However, it is important to note that ontologies are not just formal representations of a domain, but much more community contracts about such formal representations. As a dialogue is a lively public procedure, it is often prior proposals to be amended, enhanced, or even rejected, and therefore new issues are essential to be added, such a community agreement should not be passive, but capable of following the community consensus at any point in time [16].

This semantic sharing of data becomes more and more important for web resources as more and more search engines are able to read this structured data and allow a more precise recall. Even more important, ontologies allow the structuring of knowledge and the creation and disambiguation of thesauri, definitions and the general alignment of knowledge. Ontologies or vocabularies have during the recent years developed from a tool for artificial intelligence researchers to a more and more widespread technology used by domain experts and in the World Wide Web. Ontologies are there used for creating a Web of Data, which allows computers to add semantics to data, so that machines can understand them. Many domain ontologies can be found and they are not only used by experts to better structure their data, but also to allow a meaningful sharing of that data [19]. For these reasons we choose to model the gathered knowledge on climate policies under an ontology.

As shown in the above Table 1, ontologies are already adopted in numerous applications, proving their usefulness in various scientific fields [20–35]. Thus, the development of an equivalent ontology concerning climate would be a useful and efficient tool for the creation of the Climate Policy Database and the structuring of the gathered resources. Examples of ontologies used in climate applications are presented in the following Table 2.

Table 1. Ontologies in various applications.

Title	Description	Language/Interface
An Ontology to represent energy-related occupant behavior in buildings. Part I: Introduction to the DNAs framework & Part II: Implementation of the DNAS framework using an Extensible Markup Language (XML) schema [20,21]	- An occupant behavior XML schema obXML is developed. - Section 2: description of taxonomy used.	XML (eXtensible Markup Language)
Ontology of ground source heat pump [22]	- Ontology that delineates ground source heap pump (GSHP) technology. - Consists of 34 components within five levels. - Systematically highlights the critical components and delineates the GSHP system, thereby serving as a rigorous foundation for underpinning changes in government policies and industrial R&D. - Section 5: GSHP ontology.	Python, UCINET for visualization
A high-level electrical energy ontology with weighted attributes [23]	- Text analysis application. - High-level ontology for the electrical energy domain. - The ultimate ontology is aligned with the previously proposed ontologies for the energy-related subdomains after extending the latter ones with weighted attributes to handle fuzziness, multilinguality, and links to other domain ontologies as well as to other semantic information sources like Wikipedia and linked open data sources like DBpedia. - Section 3: Fuzzy Electrical Energy Ontology (FEEONT), Taxonomy.	Protégé ontology editor
A performance assessment ontology for the environmental and energy management of buildings [24]	- A semantic web based approach to the performance gap problem, describing how heterogeneous building data sources can be transformed into semantically enriched information. - A performance assessment ontology and performance framework (software tool). - Sections 2 & 3	Data in Resource Description Framework (RDF), to convert them usage of three key ontologies: ifcOWL (OWL), SimModel (XML), and SSN

Table 1. *Cont.*

Title	Description	Language/Interface
Optimization of a Multi-source System with Renewable Energy Based on Ontology [25]	- Conceptualization of the ontology after the presentation of the proposed approach. - Knowledge base which contains a representation of all concepts and informational system details. - Section 3: ontology domain, list of classes.	Protege2000 software as the editing tool
Modeling Smart Grid neighborhoods with the ENERsip ontology [26]	- Model the domain of knowledge of energy efficiency in Smart Grid neighborhoods - Resulting ontology is developed using Ontology Web Language. - Section 3: Ontology description (Tools, Classes, Domain, Relationships).	OWL DL, Protégé as ontology development environment
PV-TONS: A photovoltaic technology ontology system for the design of PV-systems [27]	- An original Semantic Web system, the photovoltaic technology ontology system (PV-TONS) that supports the management of information on PV-systems is established. - Section 4: design and implementation.	OWL, Semantic Web Rule Language (SWRL), Unified Modelling Language (UML)

Sources: [20–35].

Table 2. Ontologies and Climate.

Title	Description	Language/Interface
Ontology models of the impacts of agriculture and climate changes on water resources: Scenarios on interoperability and information recovery [36]	- OntoAgroHidro presents information on the effects of agriculture and climate changes on water resources. - Section 4: classes and interoperability of the ontology.	Web Ontology Language (OWL), SPARQL Query tab of Protégé 4.3
Ontology engineering in provenance enablement for the National Climate Assessment [37]	- A provenance-explicit ontology for the U.S. National Climate Assessment. - Tested the ontology by using it in pilot systems serving information about instances of chapters, scientific findings, figures, tables, images, datasets, references, people, and organizations, *etc.* in the draft report, as well as interrelationships among those instances. - Section 3: the Global Change Information System (GCIS) ontology.	RDF—Turtle (Terse RDF Triple Language), SPARQL queries, Dublin Core Metadata Initiative (DCMI) Types Vocabulary, Organization ontology (prefix: org), PROV-O ontology (prefix: prov), FOAF, SKOS (Simple Knowledge Organization System)

Sources: [36,37].

3. Methods

Certain knowledge gaps remain with reference to the implications of various options regarding EU and international climate policies. Achieving effective policy outcomes depends on identifying and filling these gaps.

In the above context, a methodology was applied within the framework of the Mobilizing and transferring knowledge on post-2012 climate policy implications (POLIMP) project (POLIMP is funded by the European Commission under the 7th Framework Programme—Grant Agreement No 603847) resulting in the identification of a series of knowledge needs and priorities per area of expertise. POLIMP identified and filled gaps in knowledge about climate, in order to support policy making. Its methodology focused on the identification of knowledge needs of different stakeholder groups within Europe regarding key topics of climate policy, resulting in composing knowledge packages as a response to the above needs, based on existing multidisciplinary knowledge, information and data. In addressing its goal, POLIMP developed a participatory process, including preparatory dialogue, thematic workshops and other events, questionnaire elaboration and targeted interviews with stakeholders needs (Figure 1).

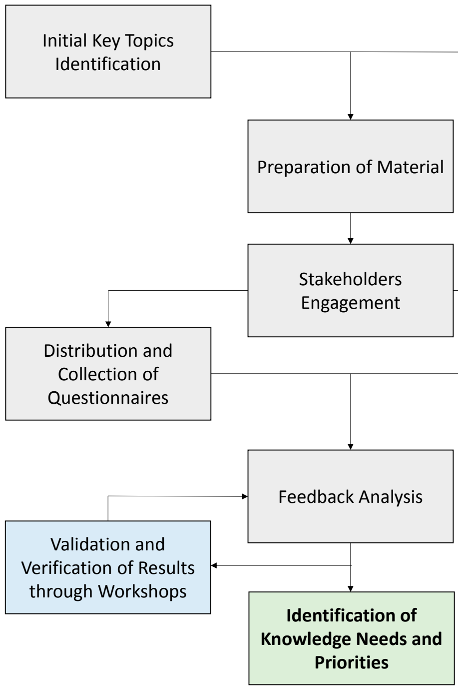

Figure 1. Methodology followed by POLIMP for identifying knowledge gaps on implications of possible directions of EU and international climate policies.

As noted above, the plethora of information on climate policy, needs to be registered and streamlined in an open input dataset, where policymakers, researchers, market actors and general public can insert their new knowledge and hence provide added value.

The implementation of the Climate Policy Database requires first a process for the identification of key areas that there is a lack of clear and targeted information in relation to the implications of future international and EU climate policy scenarios. The core objective is to cover these gaps with knowledge packages derived from a broad range of existing reports, research and climate policy decisions at, e.g., EU and UNFCCC levels.

In the above context, the knowledge gaps and needs on EU climate policy implications used for the development of this database were the finalized and validated outcomes derived from the application of POLIMP methodology, the extensive two-way stakeholder consultation process, as described in the previous paragraphs and are presented by main thematic area in Table 3 that follows.

Table 3. Key knowledge needs and priorities.

Prioritized Main Topics	Knowledge Needs
Renewable Energy	Cost-effectiveness of support schemes for renewable energy. Costs development of renewable energy technologies. Harmonisation of support schemes for renewables within and across EU member states. Smart grids.
Europe (EU) climate policy	Interaction of different climate policy instruments and different targets. Cost-effectiveness of targets. Carbon-pricing instruments (emissions trading system (ETS), taxation). Actions in other parts of the world, compared to the European Union.
International Climate Negotiations	Climate finance generating mechanisms, innovative climate finance schemes. Types and timescales of climate change mitigation targets. Vertical integration between decision-making levels.
Energy Policy	Electricity market design. Energy price developments in different world regions, and its impacts.

Table 3. *Cont.*

Prioritized Main Topics	Knowledge Needs
Energy efficiency	Effectiveness of existing energy efficiency policy. Possible energy saving obligation schemes and financing options. Energy efficiency measures savings potential. Access to capital for energy efficiency measures.
Emissions Trading	Further harmonization of emissions trading scheme implementation across the Europe (EU). Price stabilisation mechanisms, backloading, changes to the linear reduction factor. Potential reform and impacts of links to other emissions trading schemes around the world.
Financing	Incremental additional investment required in specific sectors. Mobilisation of private financial flows. Innovative finance schemes in an international context.
Adaptation	Institutional setup and organisation of mainstreaming of adaptation. Methodologies for estimation of costs and benefits of adaptation measures. Effective tools and best practices for raising public awareness and public participation. Indicators for the evidence base for adaptation policy decisions.
Agriculture & Forestry	Sustainability criteria for biomass. Indirect land use and land use, land-use change and forestry (LULUCF) accounting. Carbon sequestration. Fertiliser, manure and livestock management.
Industry	Competitiveness: carbon leakage impacts and related exemptions. Sectoral innovation scope, reduction potential and costs.
Transport	Increasing efficiency through intelligent transport systems. Efficient integration of modal networks.

The identification of knowledge needs constitutes the first step towards enhancing understanding of possible directions of climate policies among policy makers and other stakeholders and enabling them to form well-informed, consolidated decisions. The range of knowledge needs identified has to be effectively addressed by providing interested parties with suitable, to-the-point information, covering the identified gaps. This is the main goal of the Climate Policy Database.

The following steps have been defined to accomplish the objectives of the Climate Policy Database:

- Classify the resources under a hierarchical schema to facilitate search.
- Create a user centric database where users can search, view and extend the resources collected.
- Provide generic and custom views of the resources to the users of the database depending on selection criteria and tags.
- Support collaborative authoring of the available resources and their information, as well as versioning control over the changes performed in the data of the database.

The hierarchical tags of the climate policy database should have the following characteristics:

- Support different schemas: There is no generally accepted schema or ontology for representing tags. Instead, there are several ones, which provide a structuration of the tagging processes on different levels.
- Tags are the first step in creating rich semantic knowledge bases. The database should support the future evolution of tags into rich semantic annotations. The tags should be extensible with additional metadata. This facility includes labels in different languages, relations between tags and other resources as well as relations between tags.
- Users should be able to annotate resources with tags, comments, notes and all possible other attributes.
- Additional filtering support: Filter performing an equality restriction to a certain value should be supported to facilitate search. Moreover, other filter types should be allowed, such as bound/unbound property of attributes, ranges of values on a facet as well as literal expressions.

The outcome is a living database, which could be easily enhanced by relevant projects and discussion outcomes of climate negotiations and will serve as input for climate policy knowledge procession. Data and knowledge collection refer to topics of interest, such as:

- Status quo of climate policy negotiations and the EU climate policy discussion (including the climate and energy package 2020 and longer term decarbonisation and energy roadmaps).
- Identification of key trends and drivers, such as key economic, energy and demographic trends in EU and Rest of World, and trends in global land use.
- Possible international climate policy developments and scenarios based, among others, on progress in negotiation processes, observers' opinions, papers, interviews, focusing especially on what the literature says about the social, economic and environmental impacts of climate policies and the resulting impact on their political acceptability by different stakeholders.
- Information about the way policies and measures proposed in international climate policy making might work in terms of direction, strength and expected effects in different EU stakeholder contexts.

The resources used come from a wide range of up-to-date sources. Publications of the Intergovernmental Panel on Climate Change (IPCC) and those of institutions like the United Framework Convention on Climate Change (UNFCCC) secretariat, the Organisation for Economic Co-operation and Development (OECD), International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nations Environment Program (UNEP) or those of renowned researchers and institutes are considered throughout the knowledge collection process. They are of great importance and value when addressing issues like the effectiveness of a new international regime in terms of delivering the required mitigation objectives, projected socio-economic impacts, the role of low carbon technology development and transfer, relationship between climate change and land-use trends, trends in energy prices, *etc*.

More in detail, the Climate Policy Database brings together findings from: climate policy analysis projects, legal studies, studies on existing and new market mechanisms, projects on international cooperation and technology transfer and financial aspects of climate policy. Knowledge from research papers, scientific reports, decisions, articles and organizations' websites is collected, combined and utilized.

An ontology was developed for annotating and structuring the knowledge related to climate policies and provide a platform that allows exploration, editing and extension of the concentrated knowledge. The developed platform facilitates the search of information related to climate policies based on specific keywords, which in turn lowers the barrier for data re-use and integration.

4. Implementation

4.1. Information Setup and Resources

Knowledge gaps were identified for a range of priority issues related to climate policy making, in consultation with stakeholders as mentioned in the previous paragraph within the frame of POLIMP project. The gathered resources were structured by tagging them under the main issues addressed by the corresponding knowledge package. At a second level, resources are further tagged under a selection of relevant keywords in order to enhance searchability. Each resource can be tagged under one or more issues and one or more keywords. Issues and keywords are shown in the following Tables.

Main issues examined regarding climate change concern policy levels (European and International-within the UNFCCC), the issue of Adaptation to climate change, as well as three concepts that have inspired cornerstone policy instruments and targets of crucial importance, namely Emissions Trading, Renewable Energy and Energy Efficiency:

1. EU Climate Policy
2. International Climate Policy

3. Renewable Energy
4. Energy Efficiency
5. Emissions Trading
6. Adaptation

Keywords concern various aspects of climate policies including, among others, sectors to be affected, key drivers, stages of elaboration and aspects of impact measuring:

1. Targets
2. Policies
3. Industry
4. Transport
5. Households
6. Agriculture
7. Background
8. Scenarios
9. Mechanisms
10. Technology
11. Finance
12. Post 2020
13. Implementation
14. Costs & Benefits
15. Reform
16. Support systems/incentives
17. Renewable energy
18. Electricity market design
19. Increasing farm efficiency
20. Mainstreaming
21. Land use
22. International ETS

The gathered resources were structured by tagging them under the selected keywords and issues (Figure 2).

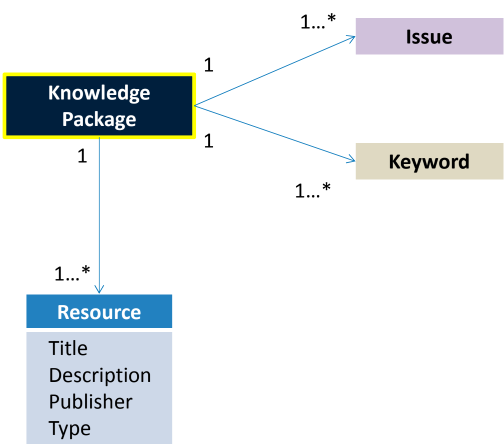

Figure 2. An ontology for representing the knowledge package resources.

4.2. Climate Policy Ontology

There are a lot of different ways to create an ontology that describes the resources of the Climate Policy Database and effectively categorize them using tags, such as the keywords and issues we described earlier. The focus of this work was to create an ontology with the use of existing standards and if and when required, to adopt new terminology to describe specific properties or concepts.

The climate policies ontology consists of two main classes the Knowledge Package class and the Climate Policies Taxonomy class. The Knowledge Package class has no further sub-classes and its instances are the knowledge packages defined in the POLIMP project. The Climate Policies Taxonomy class and its sub-classes provide us with the desired taxonomy for the information gathered. On the 1st level of sub-classes of the Climate Policies Taxonomy class we perform a first categorization on the selected issues and on the 2nd level of sub-classes we perform a further categorization on the selected keywords. The instances of the Climate Policies Taxonomy class are the collected resources. Table 4 presents the categorization we have just described.

Table 4. Main Classes and Sub-classes of the Climate Policy Ontology.

Main Classes					
EU Climate Policy	International Climate Policy	Renewable Energy	Energy Efficiency	Emissions Trading	Adaptation
Subclasses					
Background	Background	Background	Policies	Background	Background
Targets	Scenarios	Support Systems/ Incentives	Background	Implementation	Mainstreaming
Policies	Targets	Costs & Benefits	Costs & Benefits	Costs & Benefits	
Post 2020	Post 2020 Targets	Renewable Energy		Reform of the EU ETS	
Industry	Land Use	Electricity market design			
Transport	Mechanisms				
Households	Technology				
Agriculture	Finance				
Costs & Benefits	International ETS				
Increasing farm efficiency					

4.3. Technological Choices

For the implementation of the Climate Policy Database several available tools had to be considered and also the features offered by existing software had to be reviewed in order to decide the right tools, both for the database and the user interface to the database of choice.

For the backend database that stores the resources collected, there was the need to decide between the available relational databases and Triple Stores. Considering the decision to use RDF (Resource Description Framework), in order to describe the concepts of the Climate Policy ontology, a Triple Store would be the right tool to fit the implementation of a Climate Policy Database. "Triplestore" is the common name given to a database management system for RDF Data. These systems provide data management and data access via APIs (Application Programming Interface) and query languages to RDF Data. Much like a relational database, it stores information in a triplestore and retrieves it via a query language. A triplestore is enhanced for storing and recovering of triples, in contrast to a relational database. A triple is a unit of RDF Data (a graph) comprised of three pieces of information:

Subject (S), Predicate (P), and Object (O), where S and O are nodes and P the node connector (also called edge or arc). Since RDF is based on a directed graph data model the edges always point from "Subject" to the "Object" (conceptual representation (Subject) – Predicate –> (Object)). In addition to queries, triples can usually be imported/exported using RDF and other formats. Among the available Triplestores, OpenLink Virtuoso [38] was the software of choice.

For the user interface to the stored information, one option is to use standard Wiki technology, as the platform for community-driven ontology building and maintenance. A wiki would provide the support for creating Uniform Resource Identifiers (URIs) plus human-readable definitions (using text and graphics) classes, instances, and relationships of the climate policy ontology in an easy and collaborative way. Moreover, this choice offers the opportunity for a large user community to establish unique identifiers for needed concepts, resulting in more current and more complete ontology. OntoWiki [39] was the wiki of choice as it provided all the functionalities needed and even more. In the following sections OpenLink Virtuoso and OntoWiki are briefly presented.

4.3.1. OpenLink Virtuoso: A Framework for Storing and Querying Data

OpenLink Virtuoso Universal Server is a middleware and database engine hybrid that combines the functionality of a traditional Relational Database Management System (RDBMS), Object-Relational Database Management System (ORDBMS), virtual database, RDF, Extensible Markup Language (XML), free-text, web application server and file server functionality in a single system. Rather than having dedicated servers for each of the aforementioned functionality realms, Virtuoso is a "universal server"; it enables a single multithreaded server process that implements multiple protocols [40].

4.3.2. OntoWiki

OntoWiki is an open-source semantic wiki application, written in PHP and making use of either a MySQL database or a Virtuoso triple store, functioning as an ontology editor and a data acquisition system [40]. OntoWiki focuses on not confusing the users with the complication of data representation formalisms, as it is more form-based than syntax-based. OntoWiki can be installed at any Web space and accessed by an ordinary Web browser. It facilitates the visual presentation of a knowledge base as an information map, with different views on instance data. It enables intuitive authoring of semantic content, with an inline-editing mode for editing semantic content, similar to WYSIWIG for text documents.

4.4. Climate Policy Database Setup

Figure 3 depicts the schematic view of the Climate Policy Database setup with OntoWiki as a generic tool for viewing and editing the resources of the database and with OpenLink Virtuoso as the backend storage database.

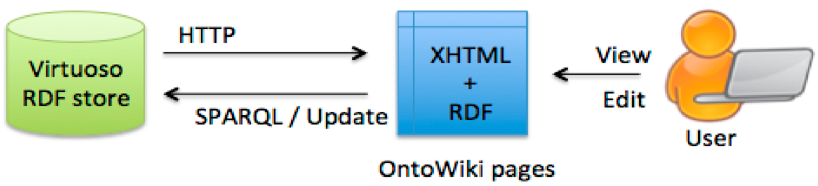

Figure 3. Climate Policy Database Setup.

To enhance, inform and erase data in OntoWiki pages, a specific element of OntoWiki named RDFauthor [39] is adopted. RDF-Author obtains RDFa [41] coded HTML data from the page's content to generate a procedure and a set of gadgets indicating this data. RDFa is the World Wide Web Consortium, W3C, proposal that permits incorporating human and machine-readable depiction inside a particular HTML file. The Climate Policy Database uses RDFa-annotations in web views, so as to make RDF model data accessible to the user. The extraction of RDF triples from RDFa-annoted Web pages and the transformation of the RDFa-annotated HTML view into an editable procedure, by using a set of authoring gadgets, are the main functions of the RDFauthor. The RDFauthor hides entirely syntax along with RDF and ontology data model obstacles from end users and permits editing data on arbitrary RDFa-annotated web pages. When the editing of all RDFa-annotated data on an OntoWiki page is finalised, the modifications are arbitrary disseminated to the Virtuoso triple store with use of the SPARQL/Update language [41].

The Climate Policy Database is an open database, easily accessible through the POLIMP project "Home" page (polimp.eu). The typical workflow of the use of the Climate Policy Database can be directly experienced through a navigation in the Climate Policy Database and is also depicted in Figure 4.

In the following paragraphs the main building blocks of the database, as well as its functionalities are presented.

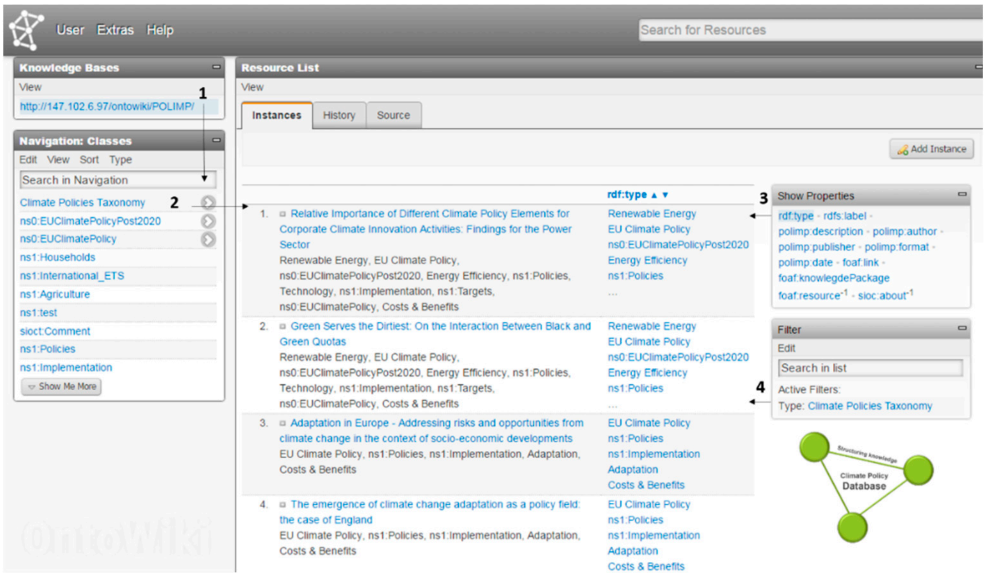

Figure 4. The Climate Policy Database: (1) Selection of a knowledge base; (2) Selection of a class; (3) Selection of additional properties to be shown as columns in the list; (4) Further restriction of the resources in the list.

4.4.1. Main Building Blocks

The Climate Policy Database user interface is separated in building blocks to facilitate their description. There are five main building blocks:

- The knowledge bases—the knowledge bases provides a list of the available knowledge bases.
- The navigation component—the navigation component is a powerful OntoWiki extension that is able to extract the structure of knowledge bases and facilitate the navigability of datasets.
- The main window—in this area the resource list of chosen class is presented. Moreover, the main window serves as a form editing area when the user selects to edit a particular resource.
- The resource search field—the resource search field enables the user to perform searches on the resources based on keywords.
- Additional modules area—in this area additional helpful modules are displayed.

4.4.2. Extending the Climate Policy database—Creating a New Class and Instances

By selecting Edit and then Add Resource here in the navigation component the user can create a new class in the Climate Policy ontology. By creating new classes the Climate Policy ontology can be extended and new tags in the pre-defined hierarchy can be added according to the needs. In addition, new instances of the available classes can be created. This enables the user to add new instances of the Climate Policies Taxonomy and Knowledge Package classes, enriching the Climate Policy Database. Depending on which class is selected in the Navigation component, a list of existing templates for the new instance's creation is presented to the user.

4.4.3. Browsing the Climate Policy database—Viewing the Instance List of a Class

By selecting one of the available classes in the navigation component, the user receives a list of resources that are instances of the selected class in the main window area.

4.4.4. Browsing the Climate Policy database—Viewing a Single Instance

The selection of a resource redirects the user to a generic resource details view in which the representation of the selected RDF triples appears as resource attribute value notation in the user interface.

4.4.5. Making changes to the Climate Policy Database—Modifying an Instance or a Class

By choosing the Edit Properties button in the single instance view, an editable form with the instance's properties appears in the main window. The user can edit the properties of the instance and also add new properties by selecting the Add Property button. In a similar way as modifying instances of the Climate Policy Database, the user is able to modify the existing classes of the Climate Policy ontology or in other words make changes to the pre-defined set of hierarchical tags.

4.4.6. Querying the Climate Policy Database—Applying Filters on the Resources

Viewing the instance list of a class by selecting the class in the navigation component provides a way on querying the Climate Policy Database based on the set of the pre-defined tags. In addition, the resource search field described earlier gives a second option for querying the database. OntoWiki also provides a third option for querying the database based on applying filters on an existing resource's list view through the Filter module. The form enables the user to apply filters on the resource list of the main window. Filters perform an equality restriction to a certain value of a resource's property. OntoWiki also supports other filter types including bound/unbound property of attributes, ranges of values on a facet as well as literal expressions.

4.4.7. Community Features

The users of the database may comment the resources available. This enables community driven discussions, for example about the validity of certain statements or the proposal of certain changes. The discussions can be performed within the Community tab of the main window area.

4.4.8. Change Tracking and Versioning

All the modifications made to a knowledge base are traced. OntoWiki allows revision of changes, such as adding new instances and classes, deleting instances and classes, modification of a specific instance, changes on instances of a class, or changes made by a distinct user. Each change committed to the database is associated with an ID. The user that performed the change, the timestamp of the change and the action type are also tracked. The user has the ability to rollback to a previous state of the resource.

5. Results and Discussion

The integration of all the data concerning climate policy making, information and negotiations, within a database system has many advantages. First, it allows for data sharing among policy makers, researchers and other stakeholders, helping to conduct research for science-based decision making.

Second, it provides users the ability to generate more information from a given amount of data than would not be possible without the integration.

Existing knowledge on climate policy was collected and clustered in an open input dataset, so as to enable a policy assessment, as well as to provide the structured content for supporting informed decisions of the policy makers, researchers, market actors and general public. A hierarchical structure of tags was created, where each tag provided semantic content to the relevant scientific studies and reports that form the resources collected. A meta-analysis was also conducted, in order to decompose the results, assumptions, factors and interactions of the numerous studies available in the literature and annotate them with the aforementioned structure of tags so that semantic search is possible through the database.

The Climate Policy Database was introduced to several stakeholders so as to receive inputs, comments and recommendations for its improvement. In addressing this, POLIMP team developed a participatory process, including preparatory dialogue, thematic workshops and other events (more than 450 participants in POLIMP workshops and events), questionnaire elaboration and targeted interviews with stakeholders (90 respondents to questionnaires, stakeholders dialogue). The stakeholders—users of the climate policy platform have expressed their content for the creation of a user centric database that users can use to search, view and extend the resources collected. They highlighted that it creates the right environment, provide a useful tool and information in a user-friendly way for key policy stakeholders to share knowledge and practical experience on climate policy, fostering collaborative knowledge exchange.

However, further features are needed to be implemented to the existing database to improve methods for assessing and comparing the existing knowledge on climate policy. More specifically, it would be helpful to develop a voting procedure for each information resource already included in the database, which can be used to evaluate the effectiveness of strategies for managing the impacts of climate change policies. This would facilitate comparisons of policy making effort in the near term—in advance of any official policy surveillance or benchmarking. Moreover, independent researchers could further analyze and synthesize these data to create some of the more challenging but informative climate policy decisions. This would allow stakeholders and other users to provide feedback on the feasibility, integrity, and precision of the database's shared information, which could be used to further refine the current pathways and options and to inform ongoing deliberations concerning climate change policy.

The Climate Policy Database could undergo further development, being enhanced through characteristics, such as a hierarchical structure of the database users. Not all users of a database system will have the same accessing privileges. For example, one user might have read-only access (*i.e.*, the ability to read a file but not make changes), while another might have read and write privileges, which is the ability to both read and modify a file. For this reason, the database could provide a security subsystem to create and control different types of user accounts and restrict unauthorized access.

In addition, it would be useful to create an event notifications service, through which information about events in the database could even be sent via email to the users. The user would then log and review changes or activity occurring on the database.

6. Conclusions

An effective response to climate change is currently high on the political agenda among the world's nations. Climate change mitigation efforts are currently intensified at an international level, as parties focus and coordinate their efforts towards an international agreement, while adaptation to climate change is in the spotlight of climate negotiations.

However, this changing and versatile political scenery of negotiations creates a wide range of possible directions and potential implications of policies on EU level, thus impeding solid policy and decision making. It necessitates further access to improved knowledge transfer and uptake for policy and decision makers, in order to render them capable of developing clear understanding of current regimes, their possible directions, implications and consequences and to support them in taking well-informed, consolidated decisions based on up-to-date reliable facts. The first step towards enhancing understanding of possible directions of climate policies among policy makers and other stakeholders is the identification of knowledge needs. In this way stakeholders are facilitated and enabled to form well-informed, consolidated decisions.

In this article the design and development of a climate policy database was presented, containing all the resources that can cover the climate policy knowledge gaps. Knowledge needs on EU and international climate policy implications were identified through POLIMP's methodology and participatory process and were presented to selected stakeholders during thematic POLIMP workshops, for feedback analysis, results review and validation. The purpose of the database is to create an ontology for interpreting and organising information associated with climate policies and to provide a platform that allows exploration, editing and extension of the concentrated knowledge.

Managing information using a database allows to become strategic users of the available data, a fact especially helpful in climate policy making, where the vast number of existing research and knowledge needs to be effectively gathered and structured. The Climate Policy Database allows regulatory agencies, governments and policy makers in general to evaluate the current regimes and their implications and impacts, and provides scientists the ability to probe and understand the outcomes of climate negotiations. The database model can be used by local governments, national, regional and international communities and academia.

The Climate Policy Database is proved to be the key element of this approach. This practical web-based application serves as a database on issues related to climate change mitigation and adaptation, technology transfer, and market mechanisms, providing numerous functionalities to make knowledge transfer as easy and accessible as possible for decision makers in policy, business and civil society. The implementation of a running living database, for annotating and structuring the knowledge related to climate policies and provision of a platform, allows exploration, editing and extension of the concentrated knowledge facilitating the decision and policy makers. The developed platform facilitates the search of information related to climate policies based on specific keywords, which in turn lowers the barrier for data re-use and integration.

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References

1. Dröge, S.; Spencer, T.; Deprez, A.; Gallagher, L.; Gradziuk, A.; Marcu, A.; Oberthür, S.; Sartor, O.; Waisman, H.; Wyns, T. *The EU's INDC and Its Contribution to a Successful Deal in Paris 2015*; Working Paper FG 8, 2015/03; Division Global Issues, Stiftung Wissenschaft und Politik, German Institute for International and Security Affairs: Berlin, Germany, 2015.
2. UNFCCC—United Nations Framework Convention on Climate Change. Adoption of the Paris Agreement, Proposal by the President, Draft decision -/CP.21 Conference of the Parties Twenty-First Session Paris, 12 December 2015. FCCC/CP/2015/L.9.

3. WHO—World Health Organization. *Climate Change and Human Health: Risks and Responses*; McMichael, A.J., Campbell-Lendrum, D.H., Corvalán, C.F., Ebi, K.L., Githeko, A.K., Scheraga, J.D., Woodward, A., Eds.; World Health Organization: Geneva, Switzerland, 2002; ISBN: 92-4-156248-X.
4. Kaygusuz, K. Energy for sustainable development: A case of developing countries. *Renew. Sustain. Energy Rev.* **2012**, *16*, 1116–1126. [CrossRef]
5. Ockwell, G.D.; Watson, J.; MacKerron, G.; Pal, P.; Yamin, F. Key Policy Considerations for Facilitating Low Carbon Technology Transfer to Developing Countries. *Energy Policy* **2008**, *36*, 4104–4115. [CrossRef]
6. Schucht, S.; Colette, A.; Rao, S.; Holland, M.; Schöpp, W.; Kolp, P.; Klimont, Z.; Bessagnet, B.; Szopa, S.; Vautard, R.; *et al.* Moving towards Ambitious Climate Policies: Monetised Health Benefits from Improved Air Quality Could Offset Mitigation Costs in Europe. *Environ. Sci. Policy* **2015**, *50*, 252–269. [CrossRef]
7. Wang, X.; Nathwani, J.; Wu, C. Visualization of International Energy Policy Research. *Energies* **2016**, *9*, 72. [CrossRef]
8. Bassi, A.M. Evaluating the Use of an Integrated Approach to Support Energy and Climate Policy Formulation and Evaluation. *Energies* **2010**, *3*, 1604–1621. [CrossRef]
9. Spyridaki, N.-A.; Ioannou, A.; Flamos, A. How Can the Context Affect Policy Decision-Making: The Case of Climate Change Mitigation Policies in the Greek Building Sector. *Energies* **2016**, *9*, 294. [CrossRef]
10. Jänicke, M. Horizontal and Vertical Reinforcement in Global Climate Governance. *Energies* **2015**, *8*, 5782–5799. [CrossRef]
11. Fujiwara, N. Status Quo of Climate Negotiations, Mobilizing and Transferring Knowledge on Post-2012 Climate Policy Implications (POLIMP) Project Report D3.1. Available online: http://www.polimp.eu/images/results/D3.1_-_Report_on_Status_Quo_of_Climate_Negotiations.pdf (accessed on 22 January 2014).
12. Ecologic Institute 2014. Report on Knowledge Needs and Priorities, Mobilizing and Transferring Knowledge on Post-2012 Climate Policy Implications (POLIMP) Project Report D5.1. Available online: http://www.polimp.eu/images/results/D5.1_Report_on_knowledge_needs_and_priorities.pdf (accessed on 15 March 2014).
13. Doukas, H.; Flamos, A.; Karakosta, C.; Psarras, J. Establishment of a European Energy Policy Think Tank Network: Necessity or Luxury? *Int. J. Glob. Energy Issues (IJGEI)* **2010**, *33*, 221–238. [CrossRef]
14. Karakosta, C.; Doukas, H.; Psarras, J. Technology Transfer Challenges within the New Climate Regime. In *Technology Transfer and Intellectual Property Issues*; Braden, A.E., Nigel, L.T., Eds.; Nova Science Publishers, Inc.: Hauppauge, NY, USA, 2010; ISBN: 978-1-60741-875-7. pp. 1–31.
15. Karakosta, C.; Ioannou, A.; Flamos, A. Mobilizing and transferring knowledge on post-2012 climate policy. In Proceedings of the 7th International Scientific Conference on Energy and Climate Change, Athens, Greece, 8–10 October 2014.
16. Hepp, M.; Bachlechner, D.; Siorpaes, K. OntoWiki: Community-driven Ontology Engineering and Ontology Usage based on Wikis. In Proceedings of the 2005 International Symposium on Wikis (WikiSym 2005), San Diego, CA, USA, 16–18 October 2005.
17. Gruber, T.R. Toward, Principles for the Design of Ontologies Used for Knowledge Sharing. *Int. J. Hum. Comput. Stud.* **1995**, *43*, 907–928. [CrossRef]
18. Guarino, N. Formal, Ontology in Information Systems. In Proceedings of the 1st International Conference (FOIS'98), Trento, Italy, 6–8 June 1998.
19. De Graaf, K.A.; Liang, P.; Tang, A.; van Vliet, H. How organisation of architecture documentation affects architectural knowledge retrieval. *Sci. Comput. Program.* **2016**, *121*, 75–99. [CrossRef]
20. Hong, T.; D'Oca, S.; Turner, W.J.N.; Taylor-Lange, S.C. An ontology to represent energy-related occupant behavior in buildings. Part I: Introduction to the DNAs framework. *Build. Environ.* **2015**, *92*, 764–777. [CrossRef]
21. Hong, T.; D'Oca, S.; Turner, W.J.N.; Taylor-Lange, S.C.; Turner, W.J.N.; Chen, Y.; Corgnati, S.P. An ontology to represent energy-related occupant behavior in buildings. Part II: Implementation of the DNAS framework using an XML schema. *Build. Environ.* **2015**, *94*, 196–205. [CrossRef]
22. Zhang, K.; Liao, P.-C. Ontology of ground source heat pump. *Renew. Sustain. Energy Rev.* **2015**, *49*, 51–59. [CrossRef]
23. Küçük, D. A high-level electrical energy ontology with weighted attributes. *Adv. Eng. Inf.* **2015**, *29*, 513–522. [CrossRef]

24. Corry, E.; Pauwels, P.; Hu, S.; Keane, M.; O'Donnell, J. A performance assessment ontology for the environmental and energy management of buildings. *Autom. Constr.* **2015**, *57*, 249–259. [CrossRef]
25. Saba, D.; Laallam, F.Z.; Hadidi, A.E.; Berbaoui, B. Optimization of a Multi-Source System with Renewable Energy Based on Ontology. *Energy Procedia* **2015**, *74*, 608–615. [CrossRef]
26. Lopez, G.; Custodio, V.; Moreno, J.I.; Sikora, M.; Moura, P.; Fernandez, N. Modeling Smart Grid neighborhoods with the ENERsip ontology. *Comput. Ind.* **2015**, *70*, 168–182. [CrossRef]
27. Nardi, J.C.; de Almeida Falbo, R.; Almeida, J.P.A.; Guizzardi, G.; Pires, L.F.; van Sinderen, M.J.; Guarino, N.; Fonseca, C.M. A commitment-based reference ontology for services. *Inf. Syst.* **2015**, *54*, 263–288. [CrossRef]
28. Abanda, F.H.; Tah, J.H.M.; Duce, D. PV-TONS: A photovoltaic technology ontology system for the design of PV-systems. *Eng. Appl. Artif. Intell.* **2013**, *26*, 1399–1412. [CrossRef]
29. Solic, K.; Ocevcic, H. The information systems' security level assessment model based on an ontology and evidential reasoning approach. *Comput. Secur.* **2015**, *55*, 100–112. [CrossRef]
30. Kurilovas, E.; Juskeviciene, A. Creation of Web 2.0 tools ontology to improve learning. *Comput. Hum. Behav.* **2015**, *51*, 1380–1386. [CrossRef]
31. Gil, R.; Virgili-Gomá, J.; García, R.; Mason, C. Emotions ontology for collaborative modelling and learning of emotional responses. *Comput. Hum. Behav.* **2015**, *51*, 610–617. [CrossRef]
32. Levine, D.M.; Dutta, N.K.; Eckels, J.; Scanga, C.; Stein, C.; Mehra, S.; Kaushal, D.; Karakousis, P.C.; Salamon, H. A tuberculosis ontology for host systems biology. *Tuberculosis* **2015**, *95*, 570–574. [CrossRef] [PubMed]
33. Lu, W.; Qin, Y.; Liu, X.; Huang, M.; Zhou, L.; Jiang, X. Enriching the semantics of variational geometric constraint data with ontology. *Comput. Aided Des.* **2015**, *63*, 72–85. [CrossRef]
34. Kontopoulos, E.; Martinopoulos, G.; Lazarou, D.; Bassiliades, N. An ontology-based decision support tool for optimizing domestic solar hot water system selection. *J. Clean. Prod.* **2016**, *112*, 4636–4646. [CrossRef]
35. Fox, M.S. The role of ontologies in publishing and analyzing city indicators. *Comput. Environ. Urban Syst.* **2015**, *54*, 266–279. [CrossRef]
36. Bonacin, R.; Nabuco, O.F.; Junior, I.P. Ontology models of the impacts of agriculture and climate changes on water resources: Scenarios on interoperability and information recovery. *Future Gener. Comput. Syst.* **2016**, *54*, 423–434. [CrossRef]
37. Ma, X.; Zheng, J.G.; Goldstein, J.C.; Zednik, S.; Fu, L.; Duggan, B.; Aulenbach, S.M.; West, P.; Tilmes, C.; Fox, P. Ontology engineering in provenance enablement for the National Climate Assessment. *Environ. Model. Softw.* **2014**, *61*, 191–205. [CrossRef]
38. OpenLink Virtuoso Universal Server. Available online: http://virtuoso.openlinksw.com/ (accessed on 3 February 2015).
39. Agile Knowledge Engineering and Semantic Web (AKSW). Available online: http://aksw.org (accessed on 10 February 2015).
40. DBpedia. Available online: http://dbpedia.org (accessed on 11 February 2015).
41. W3C Working Group Note. Available online: http://www.w3.org/TR/xhtml-rdfa-primer/ (accessed on 17 March 2015).