Renewable Energy Data Sources in the Semantic Web with OpenWatt

D. Davide Lamanna
Sapienza Università di Roma
Rome, Italy
lamanna@dis.uniroma1.it

Antonio Maccioni
Università Roma Tre
Rome, Italy
maccioni@dia.uniroma3.it

ABSTRACT

Although the sector of renewable energies has gained a significant role, companies still encounter considerable barriers to scale up their business. This is partly due to the way data and information are (wrongly) managed. Often, data is: partially available, noisy, inconsistent, sparse in heterogeneous sources, unstructured, represented through non-standard and proprietary formats. As a result, energy planning tasks are semi-automatic or, in the worst cases, even manual. As a result, the process that uses such data is exceedingly complex and results to be error-prone and ineffective. OpenWatt aims at establishing an ideal scenario in the renewable energy sector where different categories of data are fully integrated and can synergically complement each other. In particular, OpenWatt overcomes existing drawbacks by introducing the paradigm of Linked Open Data to represent renewable energy data on the (Semantic) Web. With OpenWatt, data increases in quality, tools become interoperable with each other and the process gains in usability, productivity and efficiency. Moreover, OpenWatt enables and favours the development of new applications and services.

Keywords

OpenWatt, Renewable Energy, Ontology, Linked Open Data, Web of Data

1. INTRODUCTION

Renewable Energy (RE) has a prominent market share. It will increase its popularity in the near future due to sustainability issues that are affecting the Earth.

Motivation. The report Energy [R]evolution [18] shows that employees in this sector are around the 50% of the overall energy sector. On the other hand, RE satisfies only 12.5% of European energy consumption. It sounds like the potential production and consumption are a mirage and the Europe 20-20-20[1] target is far to be reached. Actually, companies in this sector are not able to scale up their business as it should be. We ascribe such lack to the wrong way data and information are managed. Nowadays, businesses can grow quickly only if information and knowledge management is efficient, e.g., Amazon, Google, Twitter.

When a player in this sector has to conduct an energy plan or has to take important decisions about a territory, she has a limited scope of available information, because they are closed in several data silos, they use different scale, they refer different locations, they use different schemas; not to mention the not-so-rare presence of inconsistencies and errors. Correlating and integrating automatically these data is unfeasible. It follows that, the planning process requires significant manual operations and final results have approximations that can incur into errors. These deficiencies affect the tools that support business decisions. Figure 1 shows the fragmentation of actual scenario of reference, where several data sources are separated and the integration consists of different processes conducted by humans.

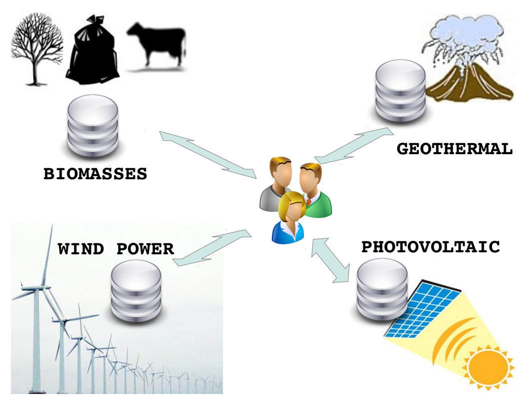

Figure 1: The actual scenario of renewable energy data managemenent.

In addition, since the scope is limited and the uniformity is poor, the tools are vertical. It means that they pursue a technology-driven approach instead of a potentiality-driven approach. They do not fully consider the potentialities of available resources in a territory. For example, let us think of the agricultural contexts where usually only solar energy is considered in the planning, while other sources (e.g., biomasses, wind power) are abundantly available. Decision

[1] http://ec.europa.eu/europe2020/index_en.htm

tools leave further big potential unexploited. Issues like these prevent the business in this sector to expand properly. OpenWatt aims at being the answer to such issues, thus providing a valid support for energy designers, local public administrations and private bodies to evaluate the energetic potential of a territory.

Contribution. OpenWatt[2] attempts to change the management of the data in the RE sector in order to overtake actual barriers. It creates a unique global database over a single schema for data about solar energy, wind energy, biomasses, etc. Data will be integrated, tools will be interoperable at data-level and, consequently, processes will be automatic. In this way, people can make rational and convenient choices and it will be much easier to guarantee self-sustainability of territories.

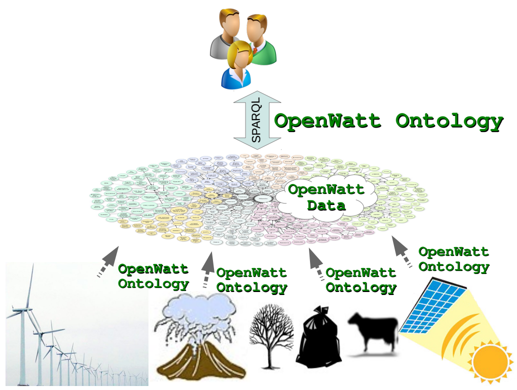

Figure 2: The scenario of renewable energy data managemenent with OpenWatt.

To this aim, OpenWatt introduces the use of Semantic Web technologies and Linked Data for energy data management problems of modelling and integration, which are recently arising [14]. The benefits that Linked Data bring about in the renewable energy sector are evident to many [1] but still there is no adopted ontology nor Linked Data to be exploited. More in details, the contributions of OpenWatt are the following:

1. Definition of a common schema (i.e. an ontology) for renewable energy data;
2. Creation of a global instance of (Linked Open) renewable energy data;

The contribution in 1) allows to share the meaning of concepts and information. In this way, we can spread the (re-)use of OpenWatt data at global scale. The definition of the OpenWatt ontology is required to guarantee interoperability among data and applications. It facilitates the understanding by both humans and automatic agents. Consequently, it will be easier to compute automatic elaborations and inferences over the data. The contribution in 2) creates the OpenWatt "data common" of available data within the Web of Data. As we will deepen in the following of the paper, we started by considering the datasets that are actually used for planning purposes. Integrating data by tracing relationships through links makes value of individual data higher. This happens because a single information is enriched by the content of data connected to it. At the moment, the RE sector is a closed world of data, applications and human resources. Hence, the greater impact of OpenWatt is the breakdown of the state of the art in this sector in order to open it up towards a new scenario based on innovation, creativity and collaboration.

In fact, since OpenWatt data will be available on the Web for everyone, people will be enabled to develop applications and services. It is a fundamental drive to open the market and create business opportunities. From the software engineering point of view, the advantage is twofold: from one hand, they can develop applications without spending much time in understanding the meaning of data (nor permission to access them); on the other hand, applications can benefit from the fact that the application back-end is leaner, as it does not need to manage a persistence layer (i.e. a database) nor duplicate and include big datasets. This is particularly beneficial to mobile applications, which have limited resources and cannot embed large datasets or compute real-time data integrations. This scenario is summarized by Figure 2, where different data sources directly feed the Web of Data. On the other side, applications and human users use a single point of access (i.e. the Web of Data) by means of the W3C standards for the Semantic Web.

Outline. The rest of the paper is organized as follows. In Section 2 we introduce some preliminary notion as well as some related work. Section 3 overviews the project, focusing in particular on the methodology to generate the data and to design the ontology. The impact and the perspectives are analysed in Section 4. In Section 5, we discuss the development of the project. Finally, in Section 6, we draw some conclusions and sketch some future perspectives for OpenWatt.

2. BACKGROUND

This section introduces the technological and social scenario where OpenWatt fits.

Open Data. The social, economical and technological scenario (i.e. crowd-sourcing, Web 2.0, mobile apps, etc.) contributed to create the Open Data concept, that is the movement of individuals and organizations who believe that public data should not "live" enclosed within data silos, but they have to be freely available on the Web. As a result, organizations such as government bodies and public administrations (PAs) have started to publish online their data [10]. Obviously, the opening and publication of data in a "raw" format is not sufficient to guarantee high quality, interoperability and re-use in the development of applications. It is crucial to provide them in a standard and machine-readable form. These issues are addressed by the protocols of the Semantic Web stack and implemented by Linked Data as explained in the following. This is the reason why many Open Data initiatives follow the Linked Data principles [4].

Semantic Web and Linked Data. The vision of the Semantic Web is to introduce a global knowledge base where data is freely available on the Web and semantically organized through the so called ontologies of reference, described with RDF and "linked" to other data. This underlies the re-

[2] `http://openwatt.net/`

placement of a Web of linked documents with a proper linked information space (Web of Data) where data are being enriched and inferred (Web of Meaning). These two concepts of Web of Data and Web of Meaning are often considered together as Semantic Web.

```
<rdf:RDF xmlns:owl =
    "http://www.w3.org/2002/07/owl#"
  xmlns:rdf =
    "http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:skos =
    "http://www.w3.org/2004/02/skos/core#"
  xmlns:rdfs =
    "http://www.w3.org/2000/01/rdf-schema#"
  xmlns:ow = "http://www.openwatt.net/">

<owl:Ontology rdf:about="http://openwatt.net/">

<owl:Class rdf:about="Municipality"></owl:Class>
<owl:Class rdf:about="Province"></owl:Class>

<owl:Class rdf:about="Region"></owl:Class>
<owl:Class rdf:about="Country"></owl:Class>
<owl:Class rdf:about="Province"></owl:Class>

<owl:Class rdf:about="Typology"></owl:Class>
<owl:Class rdf:about="Category"></owl:Class>
<owl:Class rdf:about="Measure"></owl:Class>

<owl:Class rdf:about="Potential">
    <rdfs:subClassOf rdf:resource="Typology"/>
</owl:Class>

<owl:Class rdf:about="Census">
    <rdfs:subClassOf rdf:resource="Measure"/>
</owl:Class>

<ow:Category rdf:about="Solar">
    <skos:narrower rdf:resource="Category" />
</ow:Category>

<ow:Category rdf:about="WoodyCrop">
    <skos:narrower rdf:resource="Biomass" />
</ow:Category>
    ...
<rdf:Property rdf:about="measured">
    <rdfs:domain rdf:resource="Typology" />
     <rdfs:range rdf:resource="Estimation" />
</rdf:Property>
</owl:Ontology>
</rdf:RDF>
```

Figure 3: The OpenWatt OWL Ontology.

To pursue this vision, Tim Berners-Lee proposed four principles to follow when opening data on the Web [4]: 1) use URIs to identify things; 2) use http URIs so people can look things up; 3) provide useful data in standard RDF; 4) use RDF to link to other things. Upon these principles, an Open Data rating system consisting of five levels indicated through the star symbol $\star$ was proposed[3] .

Related Work. Semantic Web technologies tackle data management tasks differently with respect to existing paradigms. For this reason, they have been proposed in different contexts as, for instance, to enable a Social Semantic Web [11]. In the energy data management, Semantic Web and Linked Data are starting to be taken into consideration [15, 8, 7, 16]. Authors of [15] and [8] use Linked Data to solve existing problems in smart environments and in domotics, including the energy management. EDF, the French electricity company uses semantic technologies to model its energy domain [7]. Linked Data principles inspired the design of an architecture for decentralised Smart Grid systems [16]. OEI (Ontology for Energy Investigations) [9], takes inspiration from the Ontology for Biomedical Investigations (OBI) to present a core ontology for energy systems. Authors of [5] state the intention to base on OWL a reasoner for their semantic modelling of life cycle assessment for energy environmental impact. The non-profit organisation for Renewable Energy and Energy Efficiency Partnership (REEP[4]) has the purpose to use renewable technologies to make improvements in the developing world. It includes 45 governments among its 385 partner organisations. REEP manages a Web portal[5] where Linked Data about partners, projects and available datasets are provided [3]. It can be possible that in the future OpenWatt will be part of the REEP data.

3. OPENWATT: DATA AND ONTOLOGY

To develop OpenWatt, we adopted a methodology that leads to the generation of the ontology of the data.

Methodology. The methodology is composed of the following steps:

1. *Data gathering:* we listed all the data available on the Web (through dumps of the datasets) that are useful for our aims, that are basically, the data actually used for the energy planning. For each dataset, we tracked all its descriptive information (e.g., meaning of the records, update frequency, licensing, etc.).
2. *Data cleaning:* this step regards the data quality. The data is analysed (in order to find inconsistencies, missings, etc.), cleaned (in order to correct errors) and normalized (in order to homogenize similar fields and different formats). At the end of the step, the datasets are more accurate and ready to be elaborated.
3. *Data modelling:* we developed a conceptual model comprising all the concepts needed and we defined relationships among these elements. We assigned names to the concepts and we defined an URI policy. Note that we considered the concepts that are represented in the datasets found in Step 1, but we did not take into consideration how they were originally modelled. Hence, we modelled them from scratch, it would have been impossible to apply a reverse engineering approach of different datasets.
4. *Data recognition:* we compared the data against the created model in order to find logical inconsistencies. At the same time, we checked if some of the concepts can be represented through existing ontologies. This

[3] http://5stardata.info/

[4] http://www.reeep.org/

[5] reegle.info

increases interoperability and understandability of our data. In particular, we reused existing concepts for geographical locations and people (e.g., core public location vocabulary[6]).

5. *Ontology definition:* the final model is formalized using the W3C standard language for ontologies on the Web, that is OWL[7] The output of this step will be explained better in the following.
6. *Data generation:* we transformed our data in RDF conforming the OpenWatt ontology. The output of this phase is explained better in the following.
7. *Metadata generation:* we enriched the information about the datasets by adding metadata, e.g., about the provenance of the datasets, the last modified date, the keywords describing the data, etc.
8. *External linking:* in this phase we linked our data to data already present in the Web of Data. External linking is intended as the process to produce RDF triples which subjects and objects belong to different datasets, that is, to bind related entities. Usually, these links represent the identity relationship between entities representing the same thing. The OWL property `sameAs` is used for the purpose. In our case, we linked our geographical entities to others already present on the Web (e.g., DBPedia[8] , Geonames[9] , etc.). This task is usually performed with record linkage tools. After this step, data is assessed with 5 stars.
9. *Data and ontology validation:* similarly to every other development process, a testing and validation task is performed. We have two different kinds of validation: syntactic and logical. The first checks if the syntax of both data and ontology are compliant to the W3C standards. Logical validation uses test cases that have to be satisfied. They are expressed through the definition of SPARQL queries. Logical problems may emerge and require the ontology to be modified, thus repeating the tasks from the third.
10. *Data publication:* we loaded our data on a triple store exposing a SPARQL endpoint[10] The endpoint is not available publicly at the moment of the issue of this paper. Once it will be published on the Web, URIs will be dereferenceable [17].

Note that some of these steps have no strict precedence over others. So, the methodology can be repeated with a different order of the steps.

Ontology. This paragraph discusses the OpenWatt ontology. Figure 4 shows the main concepts of the ontology, while Figure 4 shows an excerpt of the ontology in RDF/XML format. They point out that other ontologies such as SKOS [12], PROV [13] and GeoNames[11] have been used in OpenWatt.

[6] `https://joinup.ec.europa.eu/asset/core_location/home`
[7] Web Ontology Language - `www.w3.org/TR/owl-features/`
[8] `http://dbpedia.org/`
[9] `http://www.geonames.org/`
[10] SPARQL Query Language for RDF - `www.w3.org/TR/rdf-sparql-query/`
[11] `http://www.geonames.org/`

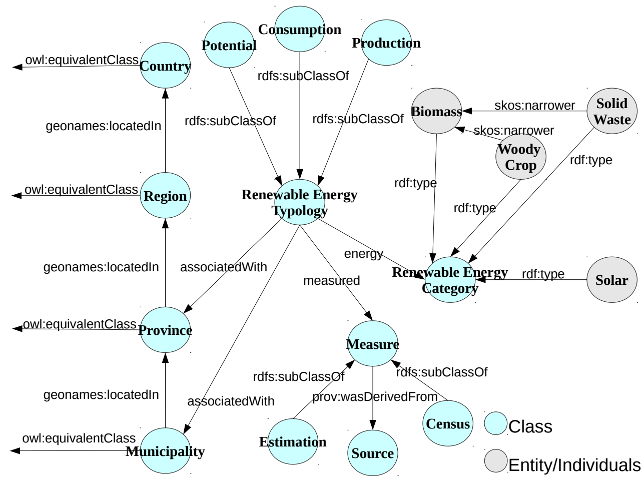

Figure 4: The OpenWatt ontology graph.

The core classes of the ontology are `Typology` (i.e. Renewable Energy Typology), `Category` (i.e. Renewable Energy Category) and `Measure`. We have three sub-classes of `Typology`: `Consumption`, `Potential` and `Production`. Every energy data value is instance of one of these classes. Their names are self-explanatory. They are also associated to (through the property `associatedWith`) a geographical location. These associations are mutually exclusively, in the sense that only one among the location taxonomy formed by `Country`, `Region`, `Province` and `Municipality` classes is valid. `Category` is a taxonomy of the existing renewable energy sources (e.g., `Biomass`, `Solar`, `Solid Waste`, etc.) implemented through SKOS [12]. `Measure` describes how the data was collected (e.g., `Estimation`, `Census`, etc.) and from which source (i.e. `Source`). Some of the relationships (i.e. `energy`) represented in Figure 4 denotes that the incident class nodes are domain and range of that property.

Data. OpenWatt contains the data we have gathered, but modelled over the ontology of the previous paragraph. In Figure 5 we have instantiated and described sample entities to understand better how data is modelled, which the full Turtle[12] serialization is in Figure 6. In the example, we have the entity `ent1` representing a potential of 10.4 GW coming from biomasses. It was estimated (i.e. `msr1`) from the source `src1`, which is itself described through the URL and the creator. `ent1` is associated to the municipality `mun1`, which is located in the province `prv2`. This province is already represented in another dataset of the Web of Data. We explicitly indicate this equivalence through a link with the property `owl:sameAs`.

The example underlines our URI policy. We have specified URI structures for classes, properties and instances. The URIs for classes follow the pattern `http://www.openwatt.net/{concept name}` where `{concept name}` is usually the name of the class, e.g., `Estimation`. The URIs for properties follow the same structure `http://www.openwatt.net/{property name}`. The URIs for the instances are structured as `http://www.openwatt.net/{concept name}/{key}`. In this case, `{concept name}` refers to the class to which the in-

[12] Terse RDF Triple Language.

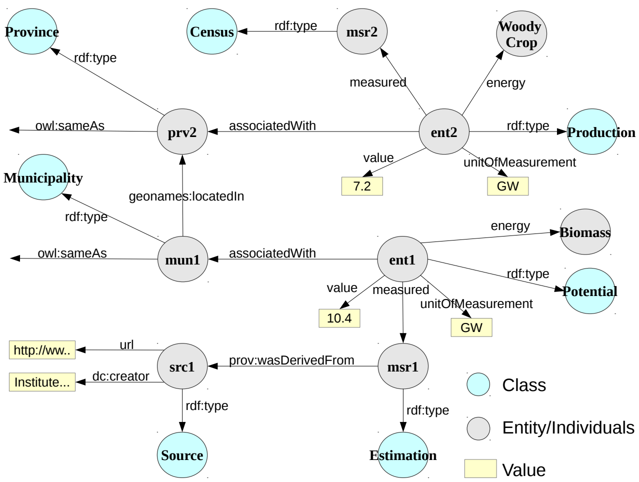

Figure 5: OpenWatt sample data graph.

stance belongs to and {key} denotes a unique alphanumeric identifier of the instance. If natural keys exist we use them[13] .

4. IMPACT AND PERSPECTIVES

In this section, we try to highlight the potential impact and the civic relevance of OpenWatt. The whole Renewable Energy sector will benefit of more efficient, convenient and accurate tools.

The work to cleaning and integrating the data is repeatedly and redundantly made by everyone approaching the matter, but it never becomes a common asset, as everyone starts it from scratch every time. OpenWatt intends to convert data in standard representations, so that everyone can directly use the data together with a high quality semantic description of their. Another positive impact of OpenWatt is on the mobility of people working in the RE sector. On-the-spot inspections and displacements, the most frequent and time-consuming activities when planning, could be considerably limited.

Public organizations are actively involved in energy management of the territories. Many of them regularly produce local energy plans, where information on provision of primary energy sources, renewable and non renewable, and on their use and consumption are collected and provided. OpenWatt returns this important patrimony in an integrated way to the tax payers.

The benefits about quality and semantic interoperability of data will be effective with the involvement and participation of PAs, citizens and enterprises. PA opens itself to citizens for the sake of transparency and direct participation to decision making processes. Apart from counting on a massive quantity of data, individual citizens and associations could contribute in a crowd-sourcing fashion to collect more data. As a matter of fact, detection tools (e.g., anemometers, small weather stations, heliometers, etc.) are often provided free of charge in exchange of data to be collected by them. This enlarges the territorial density covered by OpenWatt.

[13] A natural key is a key that is formed of attributes that already exist in the real world, e.g., the post code for a municipality.

```
@prefix ow: <http://openwatt.net/> .
@prefix rdf:
    <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix prov: <http://www.w3.org/ns/prov#> .
@prefix
    geonames: <http://www.geonames.org/ontology#> .

<http://www.openwatt.net/Potential/ent1>
    rdf:type ow:Potential ;
    ow:energy ow:Biomass ;
    ow:measured
      <http://www.openwatt.net/Estimation/msr1> ;
    ow:associatedWith
      <http://www.openwatt.net/Municipality/mun1> ;
    ow:value "10.4" ;
    ow:unitOfMeasurement "GW" .

<http://www.openwatt.net/Estimation/msr1>
    rdf:type ow:Estimation ;
    prov:wasDerivedFrom
      <http://www.openwatt.net/Source/src1> .

<http://www.openwatt.net/Municipality/mun1>
    rdf:type ow:Municipality ;
    owl:sameAs <http://www....> ;
    geonames:locatedIn
      <http://www.openwatt.net/Province/prv2> .

<http://www.openwatt.net/Source/src1>
    rdf:type ow:Source ;
    dc:creator "Institute ..." ;
    ow:url "http://www..." .
        ...
```

Figure 6: OpenWatt sample RDF Data.

Indeed, the maximum achievement of the project would be making OpenWatt a universally recognized point of reference in the RE planning for the specialists and operators of the sector.

5. IMPLEMENTATION

In this section we explain the technical work for implementing OpenWatt, providing implementation details of the phases referred in the previous section.

1. There are governmental and private energy databases used for planning purposes. At the moment of publication we are considering among the others: the Italian Atlas of solar radiation[14] that is useful for inferring potential energy from photovoltaic systems, the RSE eolic Atlas[15] containing shape files about wind measures, the National registry of zootechnics[16] containing details at municipal level about farming (e.g., pigs, cattle, horses, etc.), the GSE 2011 report on renew-

[14] http://www.solaritaly.enea.it
[15] http://atlanteeolico.rse-web.it
[16] http://www.izs.it/ZS/

able energies[17] containing production plants of different categories divided into provinces.

2. We used existing techniques and tools (e.g., relational databases) for the cleaning. For instance, we checked the values of similar concepts, we checked if there were missing rows (e.g., missing provinces), etc.
3. The work of this step is explained in the Section 3.
4. We represented manually the parts of the datasets in order to check if the model of the previous step was suitable and could represent the data correctly.
5. The work in this step is explained in Section 3 and was conducted using the editor Protégé ontology[18] .
6. Since we have heterogeneous kinds of data, several different methods were adopted in this matter. To convert CSV, TSV, relational databases and spreadsheets, we used the framework D2RQ [6], which allows to flexibly define mapping from the tabular to the RDF model. In case of shape files and Web APIs, we extracted the data and stored them into relational databases. We used PostgreSQL 9.1 as relational database management system. In case of XML source data, we used XSLT programs.
7. Most of metadata were added manually. Some other were obtained through a transformation as it happened with the data.
8. The external links were produced by configuring scripts for SILK [19], a record linkage tool for Linked Data.
9. We defined a set of SPARQL queries to assess the logical validation. For example, we checked that production data were not related to estimation measures. To validate the syntax we used the available validators: the W3C validator for the data[19] and the validator from the University of Manchester[20] for the ontology.
10. We used the triple store Openlink Virtuoso[21] to load our data. It exposes, by default, a SPARQL endpoint.

To make more efficient this long process, we will think of products for the native production of linked on the Web data from sensors (i.e. Sense2Web [2]). For facilitating the development of applications by third parties, we are setting up an open platform to develop, deploy and run applications, with useful services to link and mash-up data. The platform will expose interfaces and provide standard APIs, allowing the integration with other tools or products by means of plug-ins. Moreover, we will release all the software as Open Source, GPLv3 licensed software, for boosting the process of community development.

6. CONCLUSION AND FUTURE WORK

In this paper we have presented OpenWatt, the Web of Data space containing renewable energy data. It overcomes issues related to accessibility, interoperability and understandability of data on the Web. In this way, everyone is allowed to build applications, both mobile and Web, that facilitate the integration with legacy informative systems.

As future work, we will take into account more data as we want OpenWatt to scale at international level. This is a very challenging task since there will be the need to collect and organize massive amounts of data. The evolutionary support needs to be well-designed. In addition, the ontology will be extended according to new concepts that we will come across and we will appropriately model. We are investigating the working modes to gather data from the crowd and we are planning to develop demo applications on our data.

7. REFERENCES

[1] H. Abanda and J. H. M. Tah. Linked data in renewable energy domain. In *6th International Congress on Environmental Modelling and Software (iEMSs)*, 2012.

[2] P. M. Barnaghi and M. Presser. Publishing linked sensor data. In *SSN*, 2010.

[3] F. Bauer, D. Recheis, and M. Kaltenböck. data.reegle.info - a new key portal for open energy data. In *ISESS*, pages 189–194, 2011.

[4] T. Berners-Lee. Linked data. http://www.w3.org/DesignIssues/LinkedData.html, 2013.

[5] B. Bertin, V.-M. Scuturici, E. Risler, and J.-M. Pinon. A semantic approach to life cycle assessment applied on energy environmental impact data management. In *EDBT/ICDT Workshops*, pages 87–94, 2012.

[6] C. Bizer. D2r map - a database to rdf mapping language. In *WWW (Posters)*, 2003.

[7] P. Chaussecourte, B. Glimm, I. Horrocks, B. Motik, and L. Pierre. The energy management adviser at EDF. In *International Semantic Web Conference*, 2013.

[8] F. Corno and F. Razzak. Publishing lo(d)d: Linked open (dynamic) data for smart sensing and measuring environments. In *ANT/MobiWIS*, pages 381–388, 2012.

[9] M. Cotterell, J. Zheng, Q. Sun, Z. Wu, C. Champlin, and A. Beach. Facilitating knowledge sharing and analysis in energy informatics with the ontology for energy investigations (OEI). *Energy Informatics*, 12(4), 2012.

[10] G. Lodi, A. Maccioni, and F. Tortorelli. Linked open data in the italian e-government interoperability framework. In *6th International Conference on Methodologies, Technologies and Tools enabling e-Government (METTEG)*, 2012.

[11] A. Maccioni. Towards an integrated social semantic web. In *2nd International Workshop on Data Management in the Social Semantic Web (DMSSW)*, 2013.

[12] A. Miles and S. Bechhofer. Skos simple knowledge organization system reference. Technical report, W3C, 2009.

[13] P. Missier, K. Belhajjame, and J. Cheney. The w3c prov family of specifications for modelling provenance metadata. In *EDBT*, pages 773–776, 2013.

[14] T. B. Pedersen, W. Lehner, and G. Hackenbroich. Report on the first international workshop on energy data management (endm 2012). *SIGMOD Record*, 42(1):50–52, May 2013.

[15] F. Razzak, D. Bonino, and F. Corno. Mobile interaction with smart environments through linked data. In *SMC*, pages 2922–2929, 2010.

[16] D. Rech and A. Harth. Towards a decentralised hierarchical architecture for smart grids. In *EDBT/ICDT Workshops*, pages 111–115, 2012.

[17] L. Sauermann, R. Cyganiak, and M. Völkel. Cool uris for the semantic web. 2011.

[18] S. Teske, T. Pregger, S. Simon, T. Naegler, W. Graus, and C. Lins. Energy [R]evolution 2010: a sustainable world energy outlook. *Energy Efficiency*, 4(3):409–433, 2011.

[19] J. Volz, C. Bizer, M. Gaedke, and G. Kobilarov. Silk - a link discovery framework for the web of data. In *LDOW*, 2009.

[17] http://www.gse.it/en/pressroom/News/Pages/statistical-report-2011.aspx

[18] http://protege.stanford.edu/

[19] www.w3.org/RDF/Validator/

[20] http://mowl-power.cs.man.ac.uk:8080/validator/

[21] http://virtuoso.openlinksw.com/