EnergyUse - A Collective Semantic Platform for Monitoring and Discussing Energy Consumption

Grégoire Burel(✉), Lara S.G. Piccolo, and Harith Alani

Knowledge Media Institute (KMi), The Open University, Milton Keynes, UK
{g.burel,lara.piccolo,h.alani}@open.ac.uk

Abstract. Conserving fossil-based energy to reduce carbon emissions is key to slowing down global warming. The 2015 Paris agreement on climate change emphasised the importance of raising public awareness and participation to address this societal challenge. In this paper we introduce EnergyUse; a collective platform for raising awareness on climate change, by enabling users to view and compare the actual energy consumption of various appliances, and to share and discuss energy conservation tips in an open and social environment. The platform collects data from smart plugs, and exports appliance consumption information and community generated energy tips as linked data. In this paper we report on the system design, data modelling, platform usage and early deployment with a set of 58 initial participants. We also discuss the challenges, lessons learnt, and future platform developments.

Keywords: Energy consumption · Climate change · Semantic collective platforms · Energy monitors

1 Introduction

Global warming is one of the biggest current threats to lives, livelihoods, and economies. If unmitigated, the cost of global warming in the US alone is estimated to reach over $500 billion by 2025 [2], and to cause an average drop in global income of 23 % by 2100 [22]. The World Heath Organisation predicts that climate change will cause around 250 K additional deaths per year by 2030 due to malnutrition, disease, and heat stress.[1] The 2015 Paris Agreement on climate change emphasised the importance of raising public awareness and participation to address climate change [13]. Although most citizens are aware of the general threats of climate change, they tend to be less aware of the concrete actions that they can take to reduce carbon emissions in their homes, to more actively participate in the global fight against climate change [8,19].

Engaging people with energy conservation is a complex task [1,20], where lack of adequate consumption feedback, habitual aspects, appliances design, and

[1] WHO Climate Change and Health Fact Sheet, http://www.who.int/mediacentre/factsheets/fs266/en.

P. Groth et al. (Eds.): ISWC 2016, Part II, LNCS 9982, pp. 257–272, 2016.
DOI: 10.1007/978-3-319-46547-0_26

the choice of energy suppliers, are some of many factors that influence daily consumption of energy. Energy consumption is generally perceived at a high level [14], where the majority of people are unaware of the consumption levels of their various appliances [19]. Energy monitors could ease these issues, and have shown to lead to energy savings of 5–15% [9]. However, studies showed that energy monitors rarely attract user's attention for more than a few weeks, unless combined with other interventions, such as providing tips, motivations, and social engagement [10]

The European Environmental Agency stresses the role of technology, and of community-based initiatives, in engaging citizens and in achieving long-term behaviour change [8]. Bringing citizens together, and enabling them to compare their energy consumption levels and habits, have been found to be effective in these contexts [18].

In this paper, we introduce EnergyUse;[2] a collective awareness platform that aims to leverage the social power to engage citizens and to influence behavioural change, by encouraging people to discover, share, and discuss tips for conserving energy, and as a consequence, learn how to reduce carbon emission and help slowing climate change. With the help of electricity monitors, EnergyUse enables users to view and compare the electricity consumption of their entire households, or of specific devices and appliances. Semantics are used in EnergyUse for content augmentation from DBpedia, for environment-related tag extraction, and for Linked Data exports.

Requirements are described in the next section. Section 3 introduces EnergyUse, and in Sect. 4 we describe the usage of semantics in EnergyUse. Various evaluations are provided in Sect. 5. We end with a discussion and conclusions (Sects. 6 and 7 respectively).

2 Platform Design Requirements

Our design of EnergyUse followed a set of requirements extracted from (a) the literature, which consist of several general capabilities that were associated with successful energy saving initiatives, and from (b) community representatives, expressing their needs and interests. The following lists the recommendations gleaned from the literature:

1. **Personal approach.** The belief that climate change is a distant and non-personal threat is widespread [11]. More personal communication models are therefore needed [17,21,25], to replace generic-information based climate change campaigns, with actionable and personal experiences.
2. **Pragmatic emotions.** Rational, monetary, guilt, fear, and environmental benefits are common campaigns that tend to be ineffective in influencing citizen's behaviour towards energy and climate [15,17,23,25]. Instead, citizens should be encouraged to evaluate and understand the trade offs between environmental options and their individual values (e.g., comfort, preferences).

[2] EnergyUse, http://energyuse.eu.

3. **Social engagement.** Community initiatives tend be more successful than others in influencing energy-consumption behaviour [24]. Being a community not only encourages information exchange, it also apply more pressure to adopt, long lasting, greener social norms [8].
4. **Open discussions.** Online discussions is a promising engagement strategy for environment related topics [19]. Sharing and debating energy saving tips can provide citizens with direct feedback and concrete actions, which tend to be a highly effective intervention strategy [8].
5. **Direct feedback.** In-house energy monitors can provide households with real-time feedback on the impact of their energy consumption behaviours, thus raising their interest, understanding and awareness [6,7].
6. **Comparisons and Competitions.** Peer comparisons and competitions tend to be effective interventions in nudging towards greener behaviour [3,10].

In addition to the above, we organised 3 workshops with a group of 9 local community leaders who are active in disseminating energy conservation practices. Participants held non-technical occupations, aged between 21–72 (average age: 49.3), with an average household size of 2. In these workshops, participants discussed values, motivations and barriers related to energy savings, and shared tips and discussed energy usage in their daily routines.

The need to tackle the energy conservation subject with **personal** and **emotional** approaches constantly emerged in the discussions. For example: *"There are many things going around global warming and carbon emissions. And it scares people for discussing energy. Politicians and scientists arguing, people can have this perception.... But if you do in a light way, small actions, and in the end you say - "you saved 3 penguins", then it is ok."*. Also, against providing general hints *"If you say in kWh and carbon usage, people say, what does it mean to me? It's my hygiene standards, my time... (...) I have my lifestyle and expectations. Imagine saying to someone: you shouldn't be hoovering more than once a week."*.

In terms of **social engagement**: *"Rather than giving out leaflets or sheets of information, it is better to have a [community member] to give simple messages"*. Participants also mentioned asking neighbours for help since they are likely to have similar appliances. The need for **direct feedback** to build knowledge was frequently mentioned; *"I assume that if I use the [washing machine] eco mode I save energy, but I am not sure. It takes 3 h to wash!"*, and *"We all have this mythology to say this or that is more expensive. It is not always true"*. Beyond understanding appliances consumption, the interest in aggregating the cost of a domestic tasks also emerged: *"I would like to know how much energy I use for my breakfast"*. Participants also expressed interest in comparing the consumption of different appliances to perform similar activities, such as cooking with gas oven or microwave, or evaluating time vs efficiency: *"Sometimes less power takes longer"*, as vacuum cleaners or hair dryers.

One community leader also stated the advantages of adopting external motivations to bring people online, such as **comparison and competition**: *"some people have a natural desire to learn more about, but something to put people in,*

Table 1. EnergyUse (EU) design principles, following common guidelines from energy-related literature.

Guideline	EnergyUse design
Personal Approach	Focus on energy consumption of personal devices and appliances around the house
Pragmatic Emotions	Citizens are free to propose and discuss energy saving options in accordance with their own values and preferences
Social Engagement	Registered users are members of the EnergyUse online community site, where they can engage, interact, and influence each other
Open Discussions	Online forum for members to share and rate questions, answers, and energy saving tips
Direct Feedback	Users are equipped with electricity monitoring plugs and displays, to enable them to directly gauge their consumption, which is automatically fed into the EnergyUse platform
Comparisons and Competitions	Users can compare their own consumption against the aggregated energy consumption of appliances. Highly rated content and a high number of contributions are praised to inject an element of competition

like vouchers, might help". Table 1 shows how we designed EnergyUse to meet the requirements and guidelines described above.

3 EnergyUse Architecture and Components

EnergyUse (energyuse.eu) is a web platform designed for addressing the needs described in Sect. 2. Its development is heavily based on a customised version of BioStar[3] [16]; a Python and Django[4] based Question Answering (Q&A) software, with additional EnergyUse specific features such as concept pages, consumption data from energy monitoring devices, and linked data publication of actual energy usage of various equipment and appliances. The general architecture of EnergyUse is shown in Fig. 1. As shown in the figure, EnergyUse consists of four main modules:

- **Automatic Semantic Tagging:** This module is designed for increasing the number of concepts associated with user posts, to expand linking between conversations, and enrich the browsing experience. Third party semantic annotation tools are used by this module.

[3] BioStar, http://github.com/ialbert/biostar-central.
[4] Django, http://www.djangoproject.com.

- **Automatic Semantic Description Generator:** Topic and appliance pages on EnergyUse can be automatically populated with descriptions and background images using this module, which locates and retrieves this information from DBpedia.[5]

- **Energy Consumption Processing:** This module deals with the automatic collection of energy consumption data from user's energy monitoring devices.

- **Ontology Mapper:** Public data on EnergyUse is made available as linked data for third party tools, by mapping the data to the EnergyUse ontology.[6]

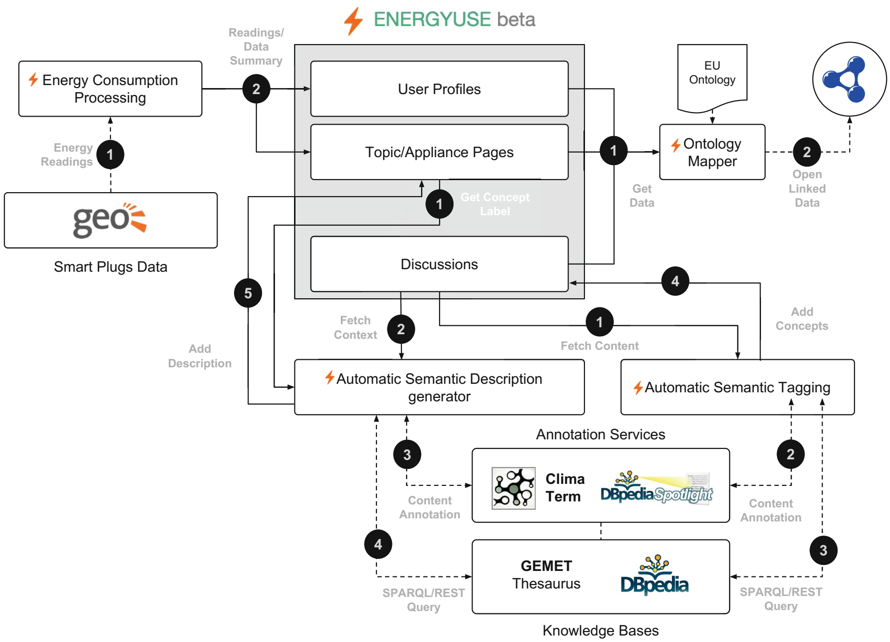

Fig. 1. Architecture and main components of the EnergyUse platform. Numbers and arrows indicate the data flow and process order for each platform modules. The modules are indicated with a *lightning bolt* symbol.

3.1 Platform Design

Figure 2 shows the front page of EnergyUse. The platform consists of three main components areas: (1) Energy related community discussions; (2) Appliance pages, and; (3) Personal energy consumption readings.

[5] DBpedia, http://dbpedia.org.
[6] EnergyUse Ontology, http://socsem.open.ac.uk/ontologies/eu.

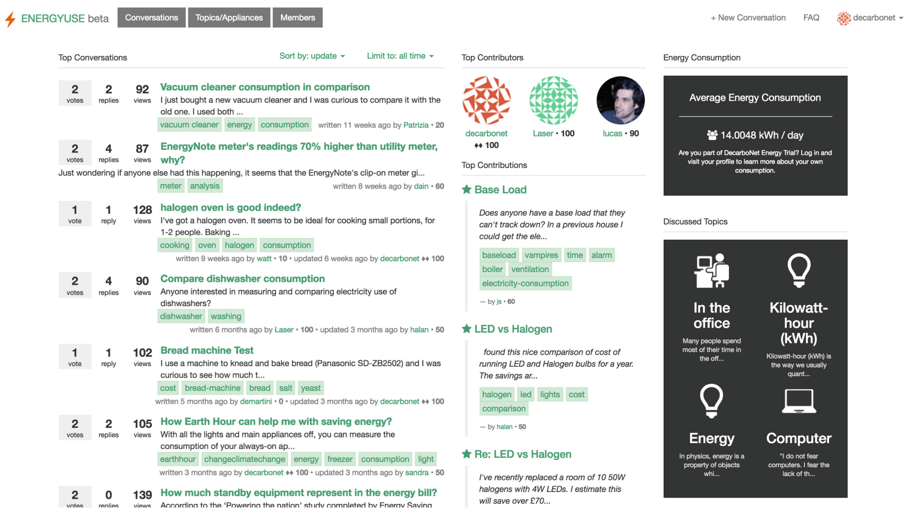

Fig. 2. The EnergyUse (energyuse.eu) homepage, displaying recent conversations, top contributors and posts, community average energy consumption, and featured topics and information.

Discussion Pages: The discussions follow the Q&A structure inherited from the Biostar platform. Each user can create discussions and post comments, "*upvote*" good posts and bookmark interesting discussions. They can also follow discussions and topics and receive email notifications when new posts are contributed. All visitors to EnergyUse can browse and read all existing discussions and public summary information about the consumption of appliances. However, only EnergyUse registered users can initiate and contribute to discussions.

Profile Pages: Profile pages contain diverse information about individual users such as their profile picture, their username, reputation score, and recent contributions. If the user connected their energy monitoring account to EnergyUse (Sect. 3.2), they can see the electric consumption of the appliances they connected to their monitoring plugs. The interface allows users to filter the display of data according to time period, type of device, and day of the week.

Appliance and Topic Pages: Posts can be tagged with keywords, which could either refer to topics (e.g., breakfast, lightening) or appliances (e.g., kettle, light bulb). Such tags are also linked with corresponding semantic concepts from DBpedia. For each topic or appliance, a dedicated page is created, containing a description, image, icon, and the list of discussions that mention that particular tag. The aim of these pages is to improve content access and topic understanding whereas the images and icons are displayed so that users feel less intimidated by the technical aspects of particular topics. If available, average energy consumption data for a given appliance will be displayed. Finally, users

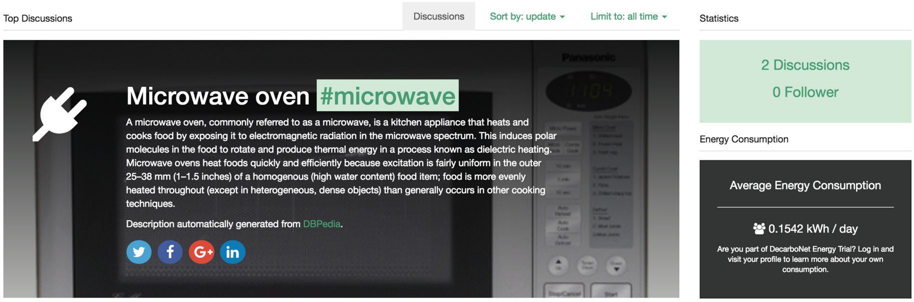

Fig. 3. EnergyUse (EU) page header of the *Microwave* appliance automatically generated using DBPedia.

can subscribe to the topic or appliance feed to receive updates of new posts. Figure 3 shows an example of a dedicated appliance page.

Tags and Users List Pages: Besides the pages above, users can view the list of all community members (registered users), to see their profile, reputations, contributions, etc. Users can also browse the list of all tags created in EnergyUse, which are linked to relevant discussion.

3.2 Connecting with Energy Monitoring Devices

One main novelty of EnergyUse is its ability to collect, visualise and publish actual appliance energy consumption information. Visitors to the platform are prompted to create an account, and to connect their energy monitoring accounts if they have one. EnergyUse currently supports energy monitoring devices from Green Energy Options (GEO)[7]. GEO enables users of their devices to select one of 41 different type of appliances for each monitoring plug they own. Examples of appliances include TV, Kettle, PC, other, etc. Energy readings from GEO devices are read by EnergyUse for registered users, thus providing them with direct, secure, and private access to their data via the platform. For privacy reasons, users are only able to view aggregated energy consumptions from all other community members, for any given appliance.

Energy consumption data is collected from GEO every 15 min,[8] and thus for each user, EnergyUse accumulates 96 readings per day per plug. When aggregating community consumption readings, outliers are removed. Outlier user-data may exist when a user moves the monitoring plug to another appliance, without changing the setup on GEO.

For each appliance where consumption data is available, EnergyUse calculates the following measurements:

[7] Green Energy Options, http://geotogether.com.
[8] GEO energy monitors send data readings once every 15 min to GEO servers.

– *Number of Observations:* We report the number of data points used for calculating the summary statistics.
– *Number of Providers:* The number of users providing the readings.
– *Number of Removed Observations:* Number of data observations found as outliers, and removed from all subsequent measurements.
– *Min Consumption:* The minimum electricity consumption recorded when the appliance is switched on (i.e. when consumption is higher than 0 kWh).
– *Max Consumption:* The maximum electricity usage observed.
– *Mean Consumption:* The average electricity consumption observed when the appliance is switched on.
– *Mean Daily Consumption:* The daily average electricity usage observed.

4 Semantic Descriptions and Modelling

Semantics are used in EnergyUse in 3 areas; (1) concept extraction from posts; (2) appliance and topic description generation from an external knowledge base, and; (3) publishing of aggregated energy consumption data as Linked Open Data (LOD). These are detailed in the following sections.

4.1 Semantic Tagging

In order to find discussions and energy consumption information more easily, user are expected to add tags when creating a discussion, to describe the appliance in question and related topics. For example, a discussion about dishwashers could be tagged with *dishwasher* appliance, *dishes*, *washing topics*, etc. To ensure that all relevant tags are generated, EnergyUse automatically identifies relevant topics and appliances from the post content, using DBpedia Spotlight[9] [5], and ClimaTerm [12].[10] entity recognition tools. With such annotation tools, EnergyUse is able to extracts concepts automatically from existing discussions and posts.

These services are designed for recognising terms in plain text and linking them with relevant concepts from different knowledge bases. In the case of DBpedia Spotlight, the knowledge is provided by DBpedia, while ClimaTerm uses GEMET[11] and REEGLE[12] as data sources. ClimaTerm is especially designed for identifying environment related terms whereas DBpedia has a more generic and higher coverage.

Since ClimaTerm specifically recognises climate-related terms, we directly use the extracted terms as additional tags. In the case of DBpedia Spotlight, we only focus on the detection of appliance related terms by adding a restriction to the type of entities identified by the tools. More specifically, we use the following SPARQL restriction to only select entities linked with the home appliance category:

[9] DBpedia Spotlight, http://github.com/dbpedia-spotlight/dbpedia-spotlight.
[10] ClimaTerm, http://services.gate.ac.uk/decarbonet/term-recognition.
[11] GEMET Thesaurus, https://www.eionet.europa.eu/geme.
[12] REEGLE, http://www.reegle.info/glossary.

```
SELECT DISTINCT ?appliance WHERE {
?appliance ?related
<http://dbpedia.org/resource/Category:Home_appliances>
}
```

4.2 Semantic Descriptions

As discussed earlier, each appliance or topic page contains a description, list of relevant tags, and a representative background image and icon. When such a page is first created (when the appropriate tag is used for the first time), there will be no description or image to describe it. This information is inserted manually by the EnergyUse administrators. As a result, such pages could remain relatively empty for a little while, especially when several of such pages are created in a short period of time. To populate such descriptive pages automatically and avoiding missing descriptions, EnergyUse retrieves relevant content from DBpedia using an approach similar to the semantic tagging method described in the previous section (Sect. 4.1).

DBpedia uses `dbo:abstract` from the DBpedia Ontology[13] for providing concept descriptions. Many DBpedia concepts also have a `dbo:thumbnail` which link to an image resource. When such information is available, we use the linked image as the background image displayed behind the concept description. When the page is automatically generated, a default "*plug*" icon is used temporarily, since no icons are available from DBpedia.

Instead of simply matching tag labels to knowledge bases directly, we use the post's text as contextual information to help the tools to disambiguate the corresponding concepts. If the annotation tools identify any concept related to the given labels, we retrieve the information mentioned above and populate the appliance or topic descriptions directly from DBPedia. To automatically verify whether or not the given page/tag is referring to a home appliance, EnergyUse detects if the corresponding DBpedia entity is associated with `dbc:Home_appliances`.

4.3 Linked Open Data Publishing

EnergyUse aggregated and anonymised energy consumption are published in JSON-LD,[14] along with all other public information on the platform. This roughly falls into four components: (1) User profiles; (2) Content data; (3) Appliances and topic information, and; (4) Energy measurements. Energy consumption of individual users is not published.

In general we reuse six different ontologies to fully represent all this data, and use `owl:equivalentClass`, `owl:equivalentProperty`, and `rdfs:sameAs` to connect EnergyUse instances with existing resources from DBpedia and GEMET. The ontology is represented in Fig. 4.

[13] DBpedia Ontology, http://dbpedia.org/ontology.
[14] JSON-LD, http://json-ld.org.

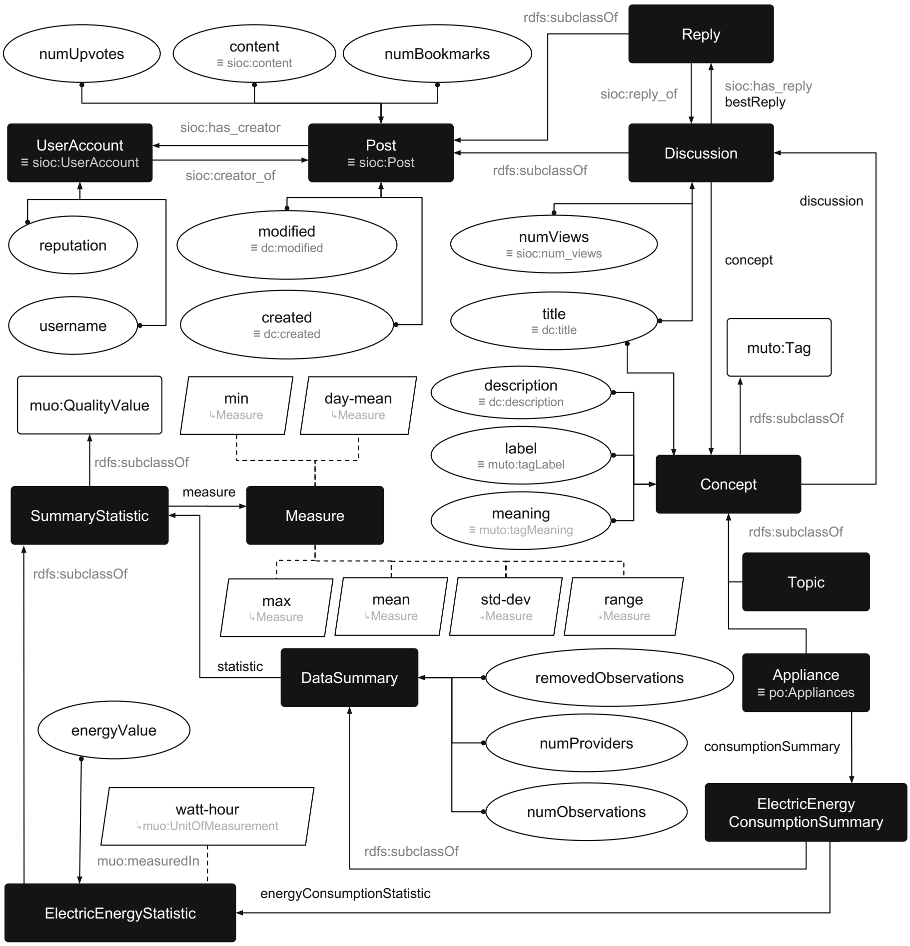

Fig. 4. EnergyUse ontology, which imports properties and classes from 6 ontologies: SIOC [4] (`sioc`), PowerOnt (`po`), MUTO (`muto`), DC Terms (`dc`), FOAF (`foaf`) and MUO (`muo`). Rectangles denote classes, ellipses properties, and parallelograms class instances.

SIOC is used to represent users and their contributions. Users' reputation is represented via a subclass of `sioc:UserAccount`, extended with `eu:reputation` and `eu:username` properties. EnergyUse discussion are not confined to Q&A, and hence to link discussions with concepts, we use `eu:Post` with an equivalence relation with `sioc:Post`. This is then extended with the `eu:Discussion` and `eu:Reply` concepts that respectively represent the initial post of a discussion and its replies. SIOC is used to represent replies (`sioc:has_reply/reply_of`) and their creators (`sioc:has_creator/creator_of`), and we add (`eu:bestReply`) as a sub-property of `sioc:has_reply` to represent best replies. New properties are used for the content, titles, upvotes, creation dates, modification dates, views and bookmarks, all appropriately linked to equivalent properties in SIOC, Dublin Core and FOAF. Each `eu:Concept` has a description, title, label and meaning, which are linked with corresponding properties in MUTO and Dublin Core. `eu:Concept` is subclassed into `eu:Appliance` and `eu:Topic`. To model tags (representing appliances and topics), we reuse and extend the Modular Unified Tagging Ontology[15] (MUTO) tag representation. FOAF `foaf:topic/page` properties are used to link topics to `eu:Discussion`. To represent the measurements in Sect. 3.2, we define `eu:DataSummary` and `eu:SummaryStatistic`, associated with multiple `eu:Measure` instances.

5 Evaluation and Analysis

In the following sections we provide various evaluations and analysis of EnergyUse.

5.1 EnergyUse User Community

Users of EnergyUse were selected as part of a general energy trial. Over 400 expression-of-interest were submitted via a dedicated online form. We then randomly selected 150 UK participants (average household size: 2.6, average age: 40.9), acquired their acceptance to our Terms & Conditions, and supplied them with energy monitoring kits, and provided installation support when needed. Few months later, we invited the participants to register with EnergyUse. 58 participants registered, and 29 of them linked their GEO account (Sect. 3.1) with the EnergyUse platform, thus allowing their energy consumption data to be read by EnergyUse. According to Google Analytics, EnergyUse so far received 520 unique visitors, generating 1,142 sessions with an average duration of 4:48 minutes, and 4,655 pageviews, with 54.4 % returning visitors.

5.2 Semantic Tag Generation

Automatic tagging (Sect. 4.1) is performed using two distinct methods: (1) ClimTerm, for adding climate related terms from the GEMET Thesaurus and REEGLE to a given discussion, and; (2) DBpedia spotlight annotations for identifying potential appliances.

In this section we focus our analysis on how the automatic tagging improved cross-concept browsing by increasing the tagging network between EnergyUse discussions. EnergyUse contained 48 tags manually created by the posts' authors. Using ClimaTerm, an additional 17 tags (concepts) were automatically generated. A full evaluation of ClimaTerm on Twitter can be found in [12]. Although ClimaTerm was evaluated on a different dataset, we do not evaluate the accuracy of ClimaTerm for our data preferring to focus on how additional tags improve user navigation between discussions.

[15] MUTO, http://muto.socialtagging.org.

With DBpedia spotlight on the other hand only found 4 concept tags, 2 of which were already found by ClimaTerm. Reason for the limited performance of DBpedia Spotlight is the enforcement of the SPARQL restriction that was presented in Sect. 4.1, which strictly limits new concept suggestions to `dbc:Home_appliances`.

In order to show that the additional tags may improve user navigation between discussions, we compute the discussion network density by considering that documents sharing the same concept tags are linked. The network density measure is the ratio between the number of observed connection between graph nodes and the number of potential node connections. The higher the value, the more likely a node can be reached from any other node. For our evaluation, we compute this measure before and after adding the new concepts through the semantic tagging approach described in Sect. 4.1. As a result, we observe that before adding concepts, the network density is 0.061 and when additional concepts are added automatically, the density rise to 0.065. This shows that although the density increase is minimal, automatic tagging may improve discussion navigation.

Such results could be enhanced further by relaxing the restrictions on the DBPedia Spotlight annotator. For example, we would obtain more concepts from discussions if we were removing the `dbc:Home_appliances` restriction. However, this could retrieve many generic concepts that might disrupt navigation in EnergyUse.

5.3 Semantic Description Generation

EnergyUse currently contains 67 concept labels, referring to topic or appliances. Remember that a page is created automatically for every new concept label. Only 25 of the 67 pages have been manually populated with descriptions and images. Here we evaluate the ability of the description generation module (Sect. 4.2) to associate DBpedia concepts to our existing labels. First we created a gold standard by manually linking all 67 labels to DBpedia. We found that only two could not be linked to any appropriate concepts. Those were *vampires* (devices that consume considerable energy even when on standby), and *baseload* (household electricity baseload). Secondly, we compare the automatic association of tags to the gold standard. Out of 67 tags, 46 were automatically linked to the exact concept as in the gold standard (69 %).

Thirdly, for the remaining 21, we check the semantic distance between the gold standard concept, and the one automatically chosen by EnergyUse. We use this to estimate how off-target the concept linking is. For different link distances $Link_d = \{0, 1, 2, 3\}$, the accuracies are respectively $Acc = \{0.69, 0.84, 0.89, 0.94\}$. In other words, 15 % of the tags were linked to DBpedia concepts that were 1 link away from the ones in our gold standard, 6 % were 2 links away, and 4 % were 3 links away. We observed that in many cases the selected concepts were more general to the gold standard. For example, the tag "*gas*" was associate with `dbo:Natural_gas` in our gold standard, and automatically linked to the broader concept of `dbo:Gas`.

Finally, we check how well did EnergyUse distinguish between topic tags and appliance tags. Out of the correctly linked 46 tags, 16 actually refer to appliances, and the 30 to topics. We found that 65 % of these tags were accurately linked to topics or to appliances. This shows that not all appliances were actually identified with `dbc:Home_appliances`. Note that such misclassifications are not impactful and directly visible to the users.

5.4 Linked Data Publishing

As discussed in Sect. 4.3, public data in EnergyUse are published in JSON-LD using the EnergyUse ontology (Fig. 4). Currently, the EnergyUse platform publishes 58 user profiles, 67 concepts, 121 posts from 38 discussions, and summarised energy consumption data for 37 appliances. Although it is early to evaluate the impact of publishing this data, we could draw insights with regards to its potential reach from the current usages of the ontologies imported in EnergyUse.

According to statistics computed in 2014 about the LOD cloud,[16] the FOAF and Dublin Core Terms were respectively used in 69.13 % and 56.02 % of the 2014 datasets crawled for computing the LOD statistics. SIOC was also highly popular with 17.65 % of the datasets using it. The other ontologies used by EnergyUse were not reported or they were not used significantly in the data crawl.

In spite of the vast amount of research on climate change related topics, there are very few energy related ontologies and datasets. This shows the potential value of the EnergyUse datasets to fill this gap and to support this rapidly growing field of research.

5.5 Scalability Assessment

As mentioned earlier, EnergyUse platform is built over the Biostar platform. This platform currently hosts the Biostars.org website which receives more than 600 user visits per hour, has nearly 26 K registered users and over 181 K posts. Different deployment modes can be used depending on the performance required. For instance, the platform has a *high traffic deployment mode* that enables asset compression and caching and a *low traffic mode* that allows for easier debugging.

Currently, the average loading time page of EnergyUse is 4.02 seconds which is sub-optimal. This is largely due to the current environment in which the server runs. Since EnergyUse is currently in still emerging and being constantly improved, the focus has been mostly on getting user feedback and rapid prototyping of necessary functionalities. For instance, features such as compression are not activated yet, as well as the cache mechanisms available in Biostar. Although we are not currently focusing on raw performance, the current platform can be easily scaled up as the large scale deployments of Biostars.org shows.

[16] State of the LOD Cloud 2014, http://linkeddatacatalog.dws.informatik.uni-mannheim.de/state.

6 Discussions and Future Work

In this section we shed light on a number of relevant issues to be addressed in near future versions of EnergyUse. Energy monitoring devices tend to be proprietary and their data are not easily accessible. Currently, EnergyUse can automatically retrieve consumption data from GEO energy monitoring devices, knowing that GEO is a major supplier of monitoring devices to British Gas;[17]. the largest energy supplier in the UK. Extending this architecture to include other monitoring devices might not be easily achievable, since it would require special agreements with various manufacturers of such devices. As an alternative, in the next version of EnergyUse we will enable users to manually enter their energy readings, which they could acquire from the energy monitoring device of their choice.

The broad use of semantic technologies in the EnergyUse platform shows how entity linking can be used for integrating external information without requiring constant human supervision. This is particularly important for websites that have a small amount of administrators and when the velocity of user contributions is outpacing manual information assessment and management (e.g. when creating topic and appliance description for newly created keywords).

LOD export currently only publishes entire discussion posts, in addition to various other public data from EnergyUse. However, some posts tend to contain concrete energy saving tips, which could be extracted in a more detail and structured fashion, thus potentially creating a valuable linked dataset. We plan to test ClimateMeasure[18] to fulfil this ambition. With regards to improving appliance-tag identification and concept-linking, beside using DBpedia Spotlight to drive this linking step, we plan to test other tools such as alchemyapi.com and textrazer.com.

EnergyUse aims to influence citizen behaviour towards greener lifestyle and habits. Next, we will study the evolution of behaviour of all members, while taking their actual energy consumption data into account, as well as the quality and quantity of their engagement and contributions on the platform. We also plan to run a user survey and usability evaluation of the platform this summer.

EnergyUse is an emerging platform and we are currently testing various interventions to increase engagement, and plan to expand the energy trials to the Netherlands which was a source of many expressions of interest (Sect. 5.1).

7 Conclusions

EnergyUse is a collective platform that targets the critical societal challenge of climate change, by raising awareness and engagement of citizens in energy-consumption discoveries and debates. One of the unique features of EnergyUse is its integration with energy monitoring devices, thus enabling users to view their

[17] GEO Press Release, http://www.mynewsdesk.com/uk/geo/pressreleases/british-gas-chooses-geo-for-next-generation-energy-displays-883182.

[18] ClimateMeasure, http://services.gate.ac.uk/decarbonet/indicators.

actual consumption levels, and to compare against community averages. Another feature is the focus on household devices and appliances, and thus bringing the topic of climate change to a personal level, and facilitating the identification of concrete and actionable energy-saving practices. In this paper, we described the rational behind EnergyUse, its user and design requirements, and detailed and evaluated the main components on the platform.

Acknowledgement. This work is funded by the EC-FP7 project DecarboNet (grant number 610829).

References

1. Abrahamse, W., et al.: A review of intervention studies aimed at household energy conservation. J. Environ. Psychol. **25**(3), 273–291 (2005)
2. Ackerman, F., Stanton, E.A.: The cost of climate change: what well pay if global warming continues unchecked (2008). https://www.nrdc.org/sites/default/files/cost.pdf
3. Allcott, H.: Social norms and energy conservation. J. Public Econ. **95**(9), 1082–1095 (2011)
4. Breslin, J.G., Harth, A., Bojars, U., Decker, S.: Towards semantically-interlinked online communities. In: Gómez-Pérez, A., Euzenat, J. (eds.) ESWC 2005. LNCS, vol. 3532, pp. 500–514. Springer, Heidelberg (2005). doi:10.1007/11431053_34
5. Daiber, J., Jakob, M., Hokamp, C., Mendes, P.N.: Improving efficiency and accuracy in multilingual entity extraction. In: Proceedings of the 9th International Conference on Semantic Systems (I-Semantics) (2013)
6. Darby, S.: Literature review for the energy demand research project. Ofgem (Office of Gas and Electricity Markets), London (2010)
7. Erhardt-Martinez, K., Donnelly, K., Laitner, J.: Advanced metering initiatives, residential feedback programs: a metareview for household energy-saving opportunities. Report no. E105. American Council for an Energy-Efficient Economy, Washington, DC (2010)
8. Agency, E.E.: Achieving energy efficiency through behaviour change: what does it that? Technical report N5/2013 (2013)
9. Hargreaves, T., Nye, M., Burgess, J.: Making energy visible: a qualitative field study of how householders interact with feedback from smart energy monitors. Energ. Policy **38**(10), 6111–6119 (2010)
10. Letwin, O., Barker, G., Stunell, A.: Behaviour change and energy use. Cabinet Office: Behavioural Insights Team (2011)
11. Lorenzoni, I., Langford, I.H.: Climate change now, in the future: a mixed methodological study of public perceptions in norwich (UK) (2001). http://www.cserge.ac.uk/sites/default/files/ecm_2001_05.pdf
12. Maynard, D., Bontcheva, K.: Understanding climate change tweets: an open source toolkit for social media analysis. In: 29th International Conference on Informatics for Environmental Protection (EnviroInfo 2015), Copenhagen (2015)
13. United Nations: Adoption of the paris agreement (2015). https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf
14. Neustaedter, C., Bartram, L., Mah, A.: Everyday activities, energy consumption: how families understand the relationship. In: Proceedings of CHI 2013, Paris, France (2013)

15. O'Neill, S., Nicholson-Cole, S.: Fear wont do it: promoting positive engagement with climate change through visual and iconic representations. Sci. Commun. **30**(3), 355–379 (2009)
16. Parnell, L.D., Lindenbaum, P., Shameer, K., Dall'Olio, G.M., Swan, D.C., Jensen, L.J., Cockell, S.J., Pedersen, B.S., Mangan, M.E., Miller, C.A., Albert, I.: Biostar: an online question & answer resource for the bioinformatics community. PLoS Comput. Biol. **7**(10), 1–5 (2011)
17. Petkov, P., Goswami, S., Köbler, F., Krcmar, H.: Personalised eco-feedback as a design technique for motivating energy saving behaviour at home. In: Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design, NordiCHI 2012, Copenhagen, Denmark. ACM (2012)
18. Petkov, P., Köbler, F., Foth, M., Krcmar, H.: Motivating domestic energy conservation through comparative, community-based feedback in mobile and social media. In: 5th International Conference on Communities & Technologies (C&T 2011), Brisbane, Australia, June 2011
19. Piccolo, L., Baranauskas, C., Fernandez, M., Alani, H., de Liddo, A.: Energy consumption awareness in the workplace: technical artefacts and practices. In: Proceedings of the 13th Brazilian Symposium on Human Factors in Computing Systems (IHC 2014), Parana, Brazil (2014)
20. Pierce, J., Paulos, E.: Beyond energy monitors: interaction, energy, and emerging energy systems. In: Proceedings of CHI 2012, Texas, US (2012)
21. Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A., Kalof, L.: A value belief norm theory of support for social movements: the case of environmental concern. Hum. Ecol. Rev. **6**(8), 81–97 (1999)
22. Sterner, T.: Economics: higher costs of climate change. Nature **527**, 177–178 (2015)
23. Sweney, M.: Government's 6m climate change ads cleared. Guardian (2010). http://www.guardian.co.uk/media/2010/oct/11/governmentclimate-change-ad
24. Umpfenbach, K.: Influences on consumer behaviour. Policy implications beyond nudging. Final report. Ecologic institute, Berlin (2014)
25. van der Linden, S.: Towards a new model for communicating climate change. In: Cohen, S., Higham, J., Peeters, P., Gossling, S. (eds.) Understanding and Governing Sustainable Tourism Mobility: Psychological and Behavioural Approaches, pp. 243–275. Routledge, Taylor and Francis (2014)