Applied Energy Symposium 2021: Low carbon cities and urban energy systems
August 24-27, 2021, Matsue, Japan
Paper ID: 80

Open Urban Data Portal for Collaborative Research and Innovation

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ABSTRACT

Data generated in the cities have great potential to assist in studies on urban metabolism and urban energy transition. Several cities around the world have already adopted the open data portals to share data and increase their capabilities. However, much of these data are of low resolution, diverse formats, and mostly lack real energy measurements of buildings. In this paper, we address this issue by using an example of Energy Hub data portal "NRGYHUB", an urban energy portal for open data for the city of Västerås, Sweden. Granular electricity, district heating and water consumption data were collected and matched to their corresponding buildings. The data are stored into a database and will be available for public through a GIS-driven interface. The challenges that were faced during the data access process are briefly described. The potential of NRGYHUB data portal as a tool to develop urban policies is discussed.

Keywords:
Open data; data challenges; data sharing portals; urban energy; urban metabolism; smart sustainable city

1. INTRODUCTION

Cities are now the primary habitat for more than 55% of the world population [1]. This expansion brings with it a slew of complicated socio-economic, technological, environmental and political dynamics that present both opportunities and challenges [2]–[5]. In addition, cities play a major role in addressing the climate change issue as they are key contributor to it, but at the same time a natural partner to mitigate its impacts [6], [7]. Moreover, as its impacts are getting more and more pronounced in urban agglomerations [8], [9], cities should manage and adapt to the urban climate change hazards.

Thus, the necessity to promote urban metabolism studies is essential for sustainable urbanization [10], [11]. Such multidisciplinary approach attempts to understand the exchange processes of energy, material, substance and environmental footprint within cities [11]. However, the complexity of such processes and of cities imposes infrastructural management problems [12]. Thanks to the advance in computational technology and IoT systems, the datafication of these processes and their underlying systems is intensifying, accelerating the transition towards "data-driven smart sustainable cities" [13]. In this context, cities have always been centers for the exchange of information [14] even though data was never been shared but rather managed by authorities. Static and historical data of cities, such as real estate registers, electricity and water consumption data shall be collected and organized. However, it is not until recently that the power of data as the new era economy has been realized. Data types, availability and accessibility (at different scales and in different dimensions-spatial and temporal) affect policy processes, but also inhibit information monopolies that limit freedom [14]. Therefore, cities should adopt the "open data" movement.

Several cities have already created their open data portals or uploaded their data on centralized data hubs [15]–[18]. However, the uploaded datasets are mainly "coarse", in means they do not provide granular detailed records, such as hourly or daily electricity consumption of houses instead of annual average consumption of specific building type. In addition, the datasets are not linked or matched together, not georeferenced neither dynamically spatially illustrated, which is important for a better understanding of the interrelationship of urban forms and structures with urban metabolism [19]–[21].
This paper presents the Energy Hub data portal, "NRGYHUB", the one of the first GIS-driven open data portal for actual granular energy usage of urban buildings in Europe. NRGYHUB provides an explicit spatial

Selection and peer-review under responsibility of the scientific committee of CUE2021

representation of the data, with a set of analytical tools. The data is preprocessed prior to its visualization and will be accessible for researchers, policy makers, urban actors, innovation companies and citizens. As an energy data portal and visualization platform, NRGYHUB can provide insights to inform city stakeholders on the current trends in energy usage and the opportunities for new technologies, such as solar energy to mitigate these needs. The granular energy data of the portal can also be used to project the energy (electricity and district heating) patterns under climate change, such as warmer days, and hazards, such as heat waves. The data portal, coupled with socio-economic and demographics statistics, will be capable to inform on the potential areas of increased electricity demand, under augmented penetration rate of electric vehicles. We believe sharing the data after the tedious collection process and pre-processing we went through has tremendous impact on the research community, enabling further findings and additional insights within the urban metabolism field, and favoring global and boarder collaboration among researchers. It is imperative to mention that NRGYHUB is not yet available online, but its first release is planed during autumn 2021.

This paper is organized as follows: Section 2 briefly presents the opportunities and challenges of open data initiatives for urban studies. Section 3 three urban data portals with similar objectives. Section 4 describes the Energy Hub data portal, NRGYHUB, its general architecture and analysis capabilities. Section 5 summarizes the presented work and presents future work.

2. OPEN DATA AND URBAN STUDIES: OPPORTUNITIES AND CHALLENGES

Many terms have been used interchangeably when referring to overlapping concepts under the open data umbrella, such as Open Data, Public Data, Open Government Data, Open Science/Research Data [22]. However, according to the review in [22], it is clear that accuracy should be considered when describing a set of data.

By definition, open data is data that can be freely used, re-used and redistributed by anyone, analyzed without copyright restrictions or barriers [22], [23].

The definition of open data does not hold any indication to their source. Yet, the term is widely used interchangeably with “Open Governmental Data” (OGD) since governments are the biggest data collectors and largest providers in most national ecosystems, and any movement for open data starts with government datasets [22]. Indeed, open data is not restricted to OGD. It may originate from public administrations, scientific (or research) entities, or from non-governmental/private companies or organizations [24], who are willing to share their data, such as industrial or technological companies.

Developing open urban data is indispensable for urban metabolism studies as previously highlighted. Within the context of sustainable cities, they generate significant opportunities for promoting inter-disciplinary and inter-organizational research, and international cooperation. Furthermore, data openness creates economic activity, solves public problems, and encourages the so-called ”citizen scientists" and empowers them, which will contribute to creating innovation [23], [25].

Yet it is a challenging task. Barriers emerge from data access and collection, all through the data processing, launching, sharing, to its use as open data.

2.1 Access and collection challenges

Researchers seek their data from different sources: personal collection through fields' visits, surveys, questionnaires, observations or experiments, research-data repositories, domain-specific portals, governmental databases and archives, published books and reports, the researchers' networks, etc. [24], [26]. The scattered status of data imposes many challenges; while some data is readily available and easy to obtain (such as buildings information and properties boundaries), many others, such as the electricity consumption, require back and forth queries to administrations and private companies holding data, to effectively communicate the purpose and description of the requested data [21]. Furthermore, data access in many cases is only granted after filling particular data requests and agreements, and/or limitations of use and disclosure, such as in the case of the Energy Atlas, where building energy data had to be aggregated before sharing data on the website [12].

2.2 *Licensing and ownership conflict*

When looking for granular data, such as electricity consumption at building level, data is not available. Not because it is absent, but rather because of privacy concerns and protection regulations such as GDPR [27], and in some cases utilities consider these data proprietary and key for their decision making processes [12]. Moreover, it is sometimes unclear which agency or administration holds a specific information, which should be made clear as part of the right to information, despite the willingness to share or not the data.

2.3 Heterogeneity

The dispersion and scatteration of data lead to its heterogeneity, in terms of spatial resolution and coverage, timescale resolution and coverage, and formats (geofiles, tables, plain texts...) [21], [24], [28]. For instance, Västerås socio-economic datasets such as the income are only available on the municipality website at the districts level. In the case of the data we obtained from Lantmäteriet (the real estate agency in Sweden), some data were obtained as geofiles, while others as txt files in tabular formats.

2.4 *Poor documentation and metadata*

Data documentation and metadata are crucial as much as the data itself. Data portal, such as Lantmäteriet, share their data with well documentation. Even though, in some cases, more explanation is required to understand the variables, and some documents are only available in the local language (Swedish in this case), imposing a language challenge. On the other hand, data provided by companies, such as the energy data from Mälarenergi (owner of the electricity, district heating and water systems in the Västerås region), has no metadata or documentation since the energy records were never intended to be fetched for sharing.

2.5 Data quality examination

It is inarguable that data collection are time and resource consuming. Therefore, sharing research data and opening data save time for not having to retrieve the same data. However, data need to be verified to be consistent, complete, clear, and reliable before publishing, which requires time and data management skills. Otherwise, it would be shared in its raw format (if no limitations are imposed), and here comes the idea of global repositories such as "the metabolism of cities data hub"[21].

3. PREVIOUS AND EXISTING INITIATIVES FOR ENERGY DATA SHARING

As discussed in the previous sections, building energy data are crucial to understand building energy use in order to address the need for sustainable and resilient cities that are capable to withstand and alleviate the climate change crisis and accelerated urbanization. However, this data is absent from online records due to many challenges and restrictions discussed in the previous section. Yet, many scientists, driven by their commitments to provide evidence-based and in-depth analysis of energy patterns and their correlation with socio-economic demographics, embark on an ambitious and implacable journey to access energy data and make it public. While many succeeds to access granular data and creates a city platform such as the case of London Building Stock Model [29], the actual data cannot be shared and thus, many failed to acquire the permission for disclosure. Next, we provide a review of three platforms for public linked urban energy data that we could find relevant to our herein study. They are the Energy Atlas developed by the University of California, Los Angeles (UCLA), the Gainesville Green project in Florida, USA, developed by a company called Acceleration in conjunction with government and university researchers, and lastly the Cambridge Building Energy and Water Use, developed by Cambridge City, USA.

The UCLA Energy Atlas [30] is a readily accessible spatial and temporal record of building energy usage in California, USA. It is considered as a repository that allows the analysis of urban metabolism by examining electricity and water use along socio-economic and spatial dimensions. Energy Atlas has an interactive tool that supports instant statistical calculations of data in the county. The timespan of the data is 10 years, from 2006 till 2016. However, the data is disclosed after a tedious spatial aggregation process. Yet, the researchers still have access to disaggregated address-level building data, which assist their further analysis on the impact of the socio-economic characteristics on energy use profiles and revealing energy injustice and fuel poverty among residents. Another project Energy Atlas supported was the estimation of the net solar potential of buildings rooftops and the impact of regulatory constraints on hindering renewable energy adoption in vulnerable communities [12], [20], [31].

The Gainesville Green [32] project is another geospatial urban utility data mapping. The aim of the project is to maximize the buildings energy efficiency and conservation in the city of Gainesville. This objective is achieved by providing houses owners and stakeholders with a set of tools to visualize their consumption history and compare it to their neighborhoods. The strategy seemed successful as the project developers noticed a reduction in energy usage of houses that were claimed on the platform. Monthly consumption of electricity, water, gas and carbon footprint is provided for claimed houses (by owners), from 2000 to 2020, a considerable long period. The data is linked to other urban features such as the building conditioned space, construction year, roof type, air conditioning system, among others.

However, the project is no longer under active development [33].

Another database is Cambridge Building Energy and Water Data Use [34] published on the city data portal. It is the result of the city enacting the Building Energy Use Disclosure Ordinance (BEUDO) in 2014, as many other US cities. The ordinance mandates owners of big buildings and large properties to measure and report annual energy use to the City, as well as make the information publicly available. The purpose is to manage the market but also for better energy efficiency in the existing buildings. However, only Cambridge City created a visualization toolkit on map or a variety of charts. As mentioned, the data is annual, which limits the analysis and possible outcomes. In addition, the data portal is exhausted with a wide set of options making it hard to navigate through.

To our best knowledge, there are no other urban energy platforms with actual high resolution linked energy data with explicit spatial mapping than the aforementioned. All datasets have undergone extensive preprocessing before publishing. In the next section, we will present NRGYHUB, the first urban energy platform and repository of actual data in Europe.

4. ENERGY HUB DATA PORTAL "NRGYHUB"

NRGYHUB is an open spatial-temporal database of utility resources consumption, with several districts in Västerås, Sweden being the first demonstrator. The data portal links high resolution measurements to real estate properties and buildings, within a GIS driven and interactive web map, allowing for historical, geographical, statistical analysis and comparisons. Our ambition for this data portal is to serve as a coherent, sustainable energy technology hub for system services in a way that can only be achieved through in-depth co-production between international, national and regional companies, research institutions and public sector. Thus, NRGYHUB would be promoted to a national data portal as more cities and urban actors get involved in this open actual data initiative.

4.1 Data portal general architecture

The data portal architecture (Fig. 1) consists of a back-end database, built using MongoDB (a NoSQL database), where hourly and monthly datasets of electricity, district heating and water consumption of houses and buildings in different areas within the city, from 2017 till June 2021 (the date on which the data was retrieved) would be stored. It also consists of a front-end (Fig. 2), which is built using React Javascript and Axios,

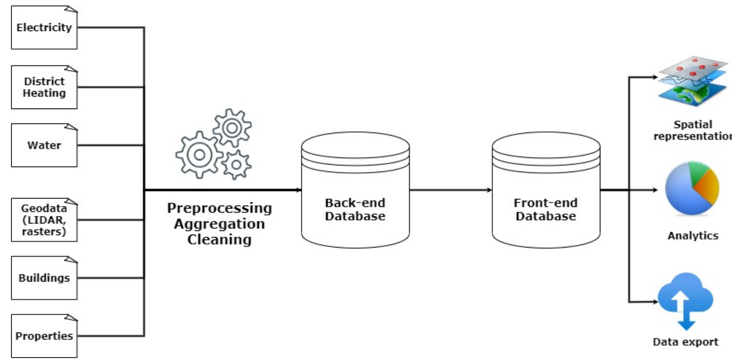

Fig. 1: NRGYHUB overview

and Leaflet libraries, for fast and easy web application. It consists of an interactive map where the datasets could be visualized with different set of analytical and statistical tools. The datasets in the database would be available cured, linking the utilities data obtained from Mälarenergi to buildings attributes obtained directly and indirectly (by computation) from Lantmäteriet such as the areas, volumes, addresses, among others. Moreover, socio-economic data such as income and age ranges are to be added once collected.

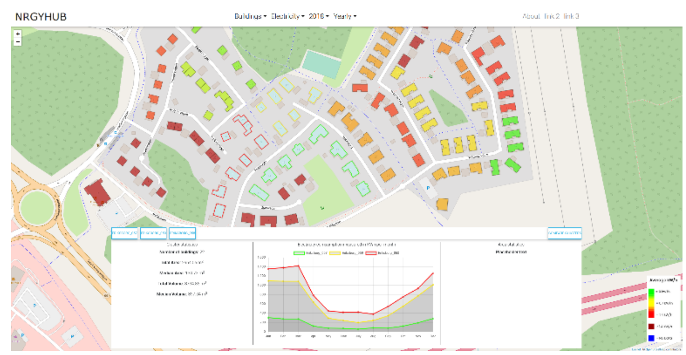

Fig. 2: Map view of early stage NRGYHUB. Polygons of buildings are shown in different colors as they belong to different electricity groups. The graph shows the actual electricity consumption of three selected groups on the map.

4.2 Methodology overview

Real estate boundaries and buildings footprints for the whole city of Västerås are collected from Lantmäteriet data portal. The datasets include the buildings type (multi-family, semi-detached, etc.) and use (residential, industrial, school, etc.). Other attributes such as the height and the volume were computed using LIDAR images and raster files.

Utilities data (electricity, district heating, and water) are obtained from Mälarenergi for five areas within the cities, representing different building types and demographics characteristics. The district heating and water data are obtained for each customer for dates ranging between 2011 and 2021, depending on the utility connection date. As for the electricity data, it is aggregated with minimum of five customers per group. It is important to note that a customer may be an apartment in a multi-family building, and thus one group may include one big building only.

4.3 Challenges

The challenges we faced while collecting the data and preprocessing it for the data portal do not differ from those reported in Section 2. As a matter of fact, buildings and properties data were downloaded from Lantmäteriet open portal for institutions (some geodata are not readily available to download without specific permission). However, part of the data was stored on an offline database that we could not know about without asking for the specific information. Regarding the energy data from Mälarenergi, records have different time resolutions (hourly and monthly). This is because hourly metering has been recently introduced to houses and facilities, and thus, the same spatial unit can have monthly records from older years and hourly records for recent ones. Furthermore, and most importantly, electricity data are only shared with us aggregated. The main reason behind this decision is that detailed energy/electricity data from smart meters are considered to fall under the General Data Protection Regulation, GDPR [27] as energy statistics on hourly level reveals information on end-user's behavior and habits. The impact of such aggregation is yet to be assessed, but such high detailed electricity data at urban scale is nowhere to be found publicly currently.

NRGYHUB has great potential for urban metabolism studies. The spatio-temporal display of energy data would allow the analysis of current and future patterns and trends, and thus derive policies and strategies to reduce consumption and increase buildings efficiency and flexibility. Moreover, the data can be used to create models of the city, such as urban energy models to assist future predictions [35]–[38], and even digital twins to assist the transition to smart cities [39]–[42]. Most of all, the coupling of the energy with socio-economic and demographics characteristics of the city would assist the identification of the energy use drivers and approach solutions from a broader multidisciplinary perspective, revealing any flaws in the energy-society nexus. On the other hand, being able to visualize their energy usage patterns and compare them to others, citizens are encouraged to engage in the transition towards sustainability, by adopting clean energy, reduce consumption and participate in the policy making by their collaboration and innovation.

5. SUMMARY

This paper discusses the current situation of open data for urban metabolism studies, in terms of opportunities, challenges and initiatives. Correspondingly, we developed an Energy Hub data portal NRGYHUB, for granular records of electricity, water and district heating consumption in Västerås, Sweden. Our attempt by this initiative is to promote more transparency, openness and sharing of data among scientists, government and data holders. By adopting the open data movement, multidisciplinary collaboration between researchers, governmental agencies and industry could be promoted for the benefit of the society. The data portal will provide a set of analytical and visualization features to effectively map and analyze energy use by emphasizing socio-economic and demographic drivers. By revealing these relationships, it will assist the transition towards more sustainable and smart cities, by providing insights on current and future consumption trends under different scenarios. The data portal targets audience of urban planners, energy actors, city managers, researchers, and citizens. An evaluation of the practical impact of such initiative, in terms of data use and developed projects, is essential after the release of NRGYHUB. In addition, feedback from targeted groups is required to enhance the usability of the data and the platform.

ACKNOWLEDGEMENT

We acknowledge the support by European Regional Development Fund (ERDF) in East Central Sweden (grant no. 20201324) governed by the Swedish Agency for Economic and Regional Growth, and the Flexergy project by the Swedish Knowledge Foundation Flexergy. Mälarenergi is acknowledged as a partner in the project working with customer access, data extraction, legal issues and problem solving.

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