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Towards an energy open science approach at district level: application to Grenoble Presqu'île

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Abstract

In this paper, we underline the interest of open science in the currently changing and challenging energy field, and hope to sketch the outline of what should be a global program to address an open design approach for energy systems at district level. This approach is based on the use case of the Grenoble Presqu'île district, on which we develop open data, open source software, open-hardware and open science contributions, all taking shape in emerging open and collaborative sites for energy research. This should enable to develop new collaborative and open organisations for energy transition, involving citizen through energy communities.

Keywords:

Open Science, Energy Modelling, Open-Data, Open-Hardware, Energy communities, Optimisation.

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1. Introduction

The design of energy system has been increasingly open in the past decade. Motivations for making energy system models open are various: a desire for improved public transparency, the need for actual scientific reproducibility, and experimenting open source development methods as a way to improve academic productivity and quality (Morrison, 2018). In this paper, we will discuss the interest of using open science in the energy field in the current context of struggle against climate change, by outlining the development of new collaborative and open



organisations, involving citizen through energy communities. A major part of this work is based on the studies led on the Grenoble Presqu'île district, that will be further described.

2. Open science in the energy field

2.1. Context of energy design and operation in cities

Nowadays, cities consume more than half of the global primary energy use, most of which is produced from fossil fuel power plants. Concurrently, climate change issues require a drastic decrease of CO₂ emissions. The development of low-carbon and decentralized renewable energies as well as the increase in energy recovery potential suggests that districts or cities will be the next place for energy production. However, these low-carbon energies create new challenges such as intermittency. Multi-carrier energy systems and flexibility appear to be answers to the intermittency issues but increase the complexity of the energy systems. Intermittency also requires taking into account the energy system operation in the pre-design studies. In addition, the shift from centralized production to district level production make new actors like local producers, prosumers or even consumers to join the incumbent actors in decision-making on energy project.

The previous considerations raise the following question: how to design an energy project and manage energy flows in order to be optimal from ecological and financial points of view? One way to help stakeholders to answer this question is to provide an open environment including open data and open models for optimization, from design to operation, in order to solve efficiently and optimally such complex problems.

2.2. Interest of open science in the energy fields

As stated hereinabove, the energy systems and their management become more complex and distributed in the current context of struggle against global warming. Energy modelling allows both researchers, citizen and policy makers to understand



these new systems. It is now crucial energy modelling and associated data become more open: open energy models and data allow for an improved quality of science and a reduction of parallel efforts, a more effective relation between science and policy, a recognition and move forward for both researchers and research community, and a transparency of scientific argument in public debate (Pfenninger et al., 2017). It can also permit citizen involvement from the early stage of the studies, which is essential to achieve successful energy transition projects (Roth et al., 2017).

In order to provide the previously mentioned open environment helping stakeholders in energy projects, several points of interest can be considered. First, open data that needs to be available, usable and homogenous. Then, making open optimisation models that can be used as decision support tools for energy projects means making the code, model and results available and understandable. Finally, an open platform can foster the previous points and the link between models, data and published articles. Such platforms entails trust between stakeholders thanks to transparency, legitimacy of studies choices and participation, and are currently linked together through networks such as Openmod¹ (Morrison, 2019a, 2019b) .

2.3. The role of energy communities

The need of an open design process in energy systems should become a must-do if we consider the possible emergence of new concepts and regulation rules. These concepts and rules can radically transform the actual energy production system from mainly centralized to a much more decentralized system in which the final consumer will be increasingly involved and play the role of energy producer. The mentioned concepts are:

- Smart-buildings integrated in smart grids, in which the inhabitants must be involved as prosumers i.e. as active and implicated designers and users in a “human in the loop” approach (Wurtz and Delinchant, 2017),

¹ <https://wiki.openmod-initiative.org>



- The Internet of energy or Enernet² that should allow the rise of prosumers as proactive participants in social energy networks and energy communities with the development of new business models that move away from simple energy metering and towards energy-related services to enhance comfort, safety, and environmental performances.

The evolution of the regulation rules going along with these new concepts are:

- The very new rules of collective self-consumption in France: since 2017, final consumers can invest together in collection system of energy production (such as photovoltaic panels), connect them to the public electrical network, and consume through this public network their own locally produced renewable energy³,
- The new European regulation of the market of energy in Europe giving a legal status to “citizen energy communities” and introducing the concept of collective self-consumption i.e. renewable self-consumers entitled to generate renewable energy, including for their own consumption, store and sell their excess production of renewable electricity fed into the grid. If living in the same multi-apartment block, they are permitted to arrange sharing of renewable energy that is produced on sites between themselves (Abada et al., 2019).

3. The Grenoble Presqu’île district: a need for energy open data and models

3.1. Study case of sustainable district energy systems

We illustrate this vision with the example of the Grenoble Presqu’île district, in which different energy systems coexist and must evolve together to meet the new

² <https://www.tenerdis.fr/en/fields-of-application/enernet/>

³ The order of 27 July 2016 on the self-consumption of electricity :

<https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000032938257&categorieLien=id>

challenges of the energy transition. Different energy networks (electric, heat) make it possible to link production systems (photovoltaic power plant, combustion of urban waste, etc.) and consumers (industries, residences, shops, vehicles, etc.).

We start from the actual case of the LNCMI. The LNCMI is the high field facility of the French National Centre for Scientific Research (CNRS) located in Grenoble. Most of its activity consists in freely providing high magnetic field to researchers from all around the world. A waste heat recovery project is under study in order to inject the electro-magnets outlet heat in the local district heating network. In addition to reducing CO₂ emissions of the local district heating network, actual challenges of waste heat recovery are addressed: power and time differences between source and consumption and the injection of heat into an existing network from a low temperature source. From a district point of view, the LNCMI can be considered as an electro-intensive industry (1) that needs to reduce its rejection of heat currently dissipated in the river (2). To do so, this waste heat can be injected in the existing district heating network (4). The buildings in the district (5) then benefit from different sources of renewable electricity (PV) and recovered heat (waste heat), but the intermittence of these energy sources requires a better control of the balance with the buildings consumption.

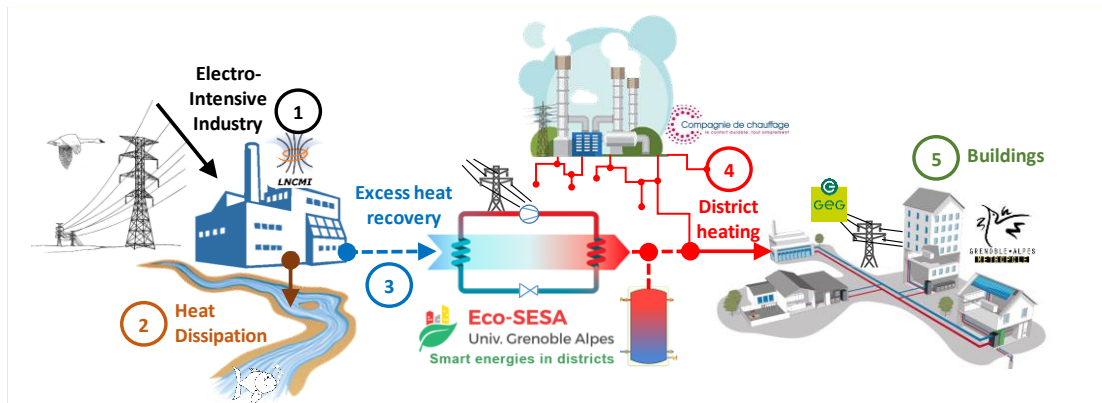


Figure 1: Grenoble Presqu'île district energy systems



This field is more particularly studied in the Eco-SESA research program⁴ in order to study:

- The heat recovery potential by optimal control of the electro-intensive industry, which on the one hand must carry out its industrial process, but whose heat rejection must be synchronized with the heat consumption of buildings (Pajot et al., 2018b)
- The capacity for actors to organize themselves to pool their energy production and consumption within energy communities, and establish trade-off solutions (Morriet et al., 2019, 2018).
- The capacity for buildings to absorb fluctuations in heating / cooling requirements without degrading the comfort of the occupants. The implementation of this flexibility of buildings should make it possible to optimize power demand on the various energy networks at the district level (Pajot et al., 2019a, 2018a).

Through this experimental field, we are going from a descending hierarchical system leading with an individualistic vision, towards a decentralized system that we want to support with a cooperative vision around the Internet of energy. To achieve this, information sharing is crucial in order to use relevant data in the models used for design and operation.

3.2. Open design of energy system based on open data

A certain number of studies must be carried out in this applied field in order to reach operational solutions that meet the challenges of the energy transition. To conduct these studies, information sharing is crucial. However, at the neighborhood level, it is particularly difficult to obtain sufficient data. The first step in our design methodology is to build a dynamic thermal model of the district suitable for optimization. In this section, we explain why proper data management is important for district model generation.

⁴ <https://ecosesa.univ-grenoble-alpes.fr/>



Contemporary cities, and particularly since the development of the concept of “smart cities”, have exposed more and more data for various users and applications. The data exposition is fostered by various actors, with corresponding privacy levels. For example, one can access building related data through the following sources:

- Open Data City Portal: Many cities today expose open data to their citizens through dedicated web platforms. For example, the city of Grenoble, France, delivers data on a web portal⁵. The released data are highly dependent on the city’s policy. One can find there infrastructure data, land registries, traffic and pollution metrics, monthly global electrical consumption, immigration rates, etc.

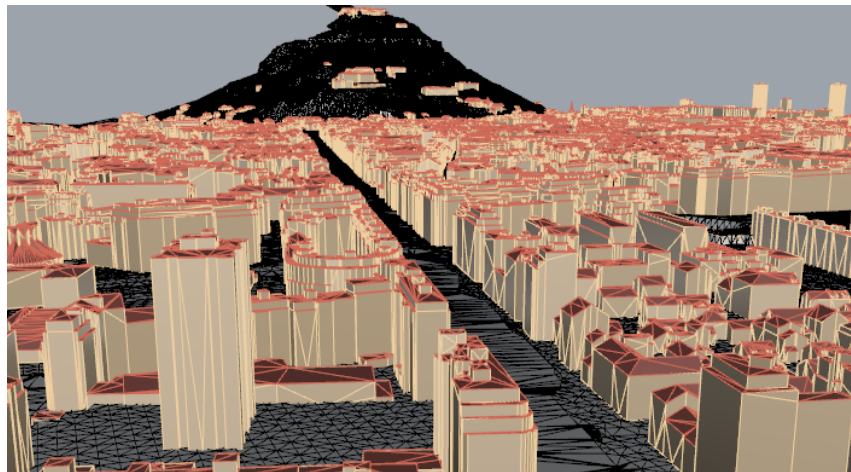


Figure 2: Grenoble buildings geometry (CityGML)

- Buildings databases, from general indicators (EU buildings database⁶: global aggregated indicators on buildings stocks, building construction dates, and consumption), to individual descriptions⁷ (PSS—Archi: community-driven inventory of European buildings—addresses, GPS coordinates, height, usage, etc.) through statistical databases (TABULA

⁵ <http://data.metropolegrenoble.fr>

⁶ <https://ec.europa.eu/energy/en/eu-buildings-database>

⁷ <http://www.pss-archi.eu>



database⁸, for statistical information about materials, usages, construction types, etc.).

- Energy certification/energy rating files: These files are dependent on a country's legislation, and generally produced before construction or during real estate transactions. For example, in France, the Thermal Regulation policy imposes the production of a "RSET" file for each new building containing structural, thermal and energy data used in a dedicated performance simulation software. They are most of the time produced by specialized engineering offices and not publicly available (one needs special inquiries to access them).
- On-site surveys: For specific projects, one can mandate surveys to recover buildings heights, number of floors, etc.
- Consumption data: Energy providers as customers have access to different aggregated consumption data according to standard privacy levels. Some data exchanges with energy providers are possible.

The main difficulties encountered by the engineer in obtaining city-scale data are the following:

- Data accessibility and variability, due to the diversity of potential providers and inherent confidentiality policies.
- Data heterogeneity, due to the many various forms such data can hold.

Data accessibility is a first challenge to address, and the scientific communities must lead the way. Another challenge is exploiting these data related to their variability and heterogeneity.

We show below in different studies that sharing these data is necessary. When this sharing does not preserve confidentiality and privacy for actors, "black box" solutions can be envisaged (Raad et al., 2015): using the European Union approach

⁸ <http://episcopes.eu/welcome/>



regarding open access, data should be “as open as possible, as closed as necessary”⁹ for commercial, ethical and security concerns for instance.

The district presented in the Figure 1 is more particularly studied in the Eco-SESA research program:

- Using Extraction–Transformation–Loading (ETL) technic, it is possible to use an heterogeneous set of data (as previously presented) to achieve the complete modeling of a neighborhood (Pajot et al., 2019b).
- Use of historical data of electrical intensive industry to apply time series pattern recognition to extract relevant information for optimal modeling and control using OMEGAlpes (Pajot et al., 2019d). OMEGAlpes will be described further below.
- Monitoring household consumption, using different ways from Linky data (1/2h time step) to open-source hardware for the mass distribution of high accuracy energy monitoring¹⁰.
- Online real time energy data of the GreEn-ER building (engineering school and laboratories) published openly on the public domain, which aims to extend to the citizen the methods and technologies to contribute to the energy transition using open science¹¹.

These studies illustrate the “as open as possible, as closed as necessary” principle for data sharing: open data is available from education and laboratories buildings, while heat and electrical consumptions of the district inhabitants are necessarily closed for privacy reasons.

Open data can then be used in energy models for the design and operation of energy systems. OMEGAlpes¹² was developed in this sense: it is an open source software

⁹ https://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/open-access-data-management/open-access_en.htm

¹⁰ <https://tinyurl.com/electricity-monitoring>

¹¹ <http://mhi-srv.g2elab.grenoble-inp.fr/API/>

¹² <https://omegalpes.readthedocs.io/en/latest/>



that facilitates the design time of energy systems and that enables to share methods of design for energy systems using Mixed Integer Linear Programming (MILP) (Pajot et al., 2019c).

We will develop the previous points in the full paper version.

3.3. The Grenoble Presqu'île: towards an open research district for energy

Through the mentioned studies, Grenoble Presqu'île has the potential to become an open research district in the energy field:

- Energy consumption and production open data are used for research and training,
- Open models, methods and tools such as the technical, economic and environmental ones using OMEGAlpes have been specifically developed and applied (Hodencq et al., 2019).
- Upcoming production consists in the development of a collaborative open research platform for the hosting laboratory where data, models and tools will be made available

From a research on district sustainable energy systems and optimization modelling tools with a focus on open science, can emerge open research sites: an online platform and a physical district that can both incorporate or initiate and embody networks for open science. Such sites and networks ought to be key elements for the energy transition.

4. Outline of the main features in open design processes with regard to the challenges for the energy transition

Thanks to this paper, we hope to sketch the outline and contribute to what should be a global program and perspective to address an open design approach for energy systems at district level. This approach, based on the use case of the Grenoble



Presqu'île district, on which we develop open data, open source softwares, open-hardware and open science contributions, will help us to identify:

- the actors that should use those open source approaches: they can be traditional stakeholders of the energy industry (electrical companies, heating companies, ...), but also emerging actors such as the prosumers that will contribute to develop and to use local energy systems in energy communities,
- the topics on which those open source approaches should be applied: the paper has focused on waste heat recovery at district level, but other topics must be addressed such as the local valorisation of solar or wind energy,
- the items on which those open science approaches should be applied: it could be software approaches for the design or the supervision of energy systems. It could also consist in the development of hardware components for production, storage, or measurements that could typically be led in an open hardware approach for design and implementation.

This should enable to develop new collaborative and open organisations for energy transition that can even involve civil society organizations and citizen science projects founded to promote very rapid decarbonisation¹³ (Morrison, 2019b, 2019a). They should facilitate collaboration in a horizontal way between actors working together more and more in a peer to peer approach what seems to be possible to emerge in an internet of energy approach. In any case, the solution explored should have the property of being massively replicable in order to have a real impact in the energy transition.

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¹³ : see as an exemple the following initiative : <https://forum.openmod-initiative.org/t/energy-bridge-meeting-on-18-january-2020-in-berlin/1792>



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