Abstract

This paper focuses on the characterization of the energy demand and the locally available renewable resources for an existing and dense urban district. Objective is setting up an integrated spatio-temporal database, for the evaluation of diverse strategies concerning the integration of renewables in the existing urban fabric. In a first step, the various demands (heating, cooling and electricity) are characterized in terms of annual values and spatial distribution (at building level), by merging of diverse databases containing actual monitored values, in combination with specific models for the completion of missing data, and for split up in terms of the various usages. In a second step, the aggregated demands (at district level) are characterized in terms of hourly dynamic, for a common reference year, by re-scaling of monitored load curves. Similarly, the existing resources (solar, hydro- and aero-thermal) are characterized by way of monitored values, in terms of hourly dynamic (for the same common reference year), as well as spatial distribution (in particular concerning solar irradiation on building roofs and [...]
Spatial and temporal characterization of energy demand and resources for an existing and dense urban district in Geneva

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Abstract

This paper focuses on the characterization of the energy demand and the locally available renewable resources for an existing and dense urban district. Objective is setting up an integrated spatio-temporal database, for the evaluation of diverse strategies concerning the integration of renewables in the existing urban fabric.

In a first step, the various demands (heating, cooling and electricity) are characterized in terms of annual values and spatial distribution (at building level), by merging of diverse databases containing actual monitored values, in combination with specific models for the completion of missing data, and for split up in terms of the various usages. In a second step, the aggregated demands (at district level) are characterized in terms of hourly dynamic, for a common reference year, by re-scaling of monitored load curves. Similarly, the existing resources (solar, hydro- and aero-thermal) are characterized by way of monitored values, in terms of hourly dynamic (for the same common reference year), as well as spatial distribution (in particular concerning solar irradiation on building roofs and geothermal resources).

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### Nomenclature

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AC</td>
<td>air conditioning (cooling)</td>
</tr>
<tr>
<td>DHW</td>
<td>domestic hot water</td>
</tr>
<tr>
<td>GIS</td>
<td>geographic information system</td>
</tr>
<tr>
<td>HP</td>
<td>heat pump</td>
</tr>
<tr>
<td>PV</td>
<td>photovoltaics</td>
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<tr>
<td>SH</td>
<td>space heating</td>
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</table>

1. Introduction

Realization of the energy transition will require both, reduction of the energy demand in buildings and substitution of fossil fuels by renewable energy. However, strategic planning for exploiting renewable resources needs a fair knowledge of the spatial and temporal distribution of these local resources, as well as of the energy demand of the related building stock.

Such is in particular the case for the heating and cooling sectors, where transportation over large distances is prohibitive. Moreover, these issues are specifically relevant for existing and dense urban districts, where sufficient demand density make the integration of thermal networks possible, and where coincident heating and cooling may represent an important potential for synergies.

The objective of this study is to set up a homogeneous spatio-temporal demand and resource database for a typical, existing and dense urban district situated in the city center of Geneva (Switzerland). Most of the demand GIS-data (annual values) comes from diverse existing databases, which were compiled and completed for the sake of the study. District aggregated data (in terms of hourly dynamic over a common reference year - 2015) is obtained by re-scaling of actual, monitored load curves, as well as by other existing datasets.

2. The Jonction district

The Jonction district (95.8 ha) consists of a typical, existing and dense urban fabric of the city of Geneva, situated at the junction of the Rhône and Arve rivers, some 2 km off the lake.

An important portion of the district is currently the object of a planned district heating and free cooling network whose construction should start in 2017 [1, 2]. The heat network will be supplied with a centralized HP on lake water (10 MW) and gas/oil boilers for peak loads (22.8 MW); the free cooling network, with lake water (0.6 MW). The project includes an additional 10.2 ha of built environment on the other side of the Rhône, which is therefore included in this study.

The 855 existing buildings concern diverse categories (58% multifamily residential, 25% industry, 9% services and administration, 4% teaching facilities) and ages (mainly from the early 20th century and up to the 60s, with a few more recent buildings). Presently, nearly all of these buildings are equipped with gas or oil fired boilers (at building level).

3. Demand

3.1. Heat demand

Annual values for SH and DHW demand are derived from the heating index database of the Canton of Geneva [3], which contains GIS information, at building level, on the heated floor area, the associated energy career, as well as the climate corrected final energy for heat production, measured over several years of operation. In the case of the Jonction district, the database covers 65% of the building stock, respectively 85% of heated surface. For the remaining...
buildings, the missing data are derived from a recently developed GIS heat demand model of the Swiss building stock [4].

For each building, the heat demand is computed by way of an average heat production efficiency, which depends on the energy career [3]. Finally, SH demand is estimated by subtracting the DHW demand, itself derived from standard values for different building categories [3]. This procedure allows setting up a GIS database covering the entire district (Fig. 1). At aggregated level, the district comprises 161.5 ha of heated surface, with 177.9 GWh annual heat demand (154.4 GWh SH, 23.5 GWh DHW), i.e about 4% of the building heat demand of the Canton [5].

Hourly profiles of these spatially aggregated demands are constructed by the upscaling of the aggregated SH and DHW load curves of the Laurana multifamily residential complex (33.5 ha heated surface), also situated in Geneva, which was recently connected to a district heating network [6]. In 2015, the annual heat consumption of these buildings (measured at the level of the 6 substations), amounted to a total of 4.3 GWh (69% SH, 31% DHW). The representativeness of this specific building complex of the 60s, in terms of load profile, could be questioned. However, the comparison of 5 different district heating networks situated in Geneva, with very distinct distributions in terms of building category and building age, shows a very homogeneous behavior in terms of sorted load curves [7], which speaks in favor of our procedure.

The resulting load curves for the Jonction district are presented in Fig. 2, in terms of hourly and daily average values. Hourly peak values amount to 65.1 MW SH and 7.0 MW DHW, for a combined 65.2 MW total heat demand (non-simultaneous peak loads). Daily average peak values amount to 52.4 MW SH and 3.5 MW DHW, for a combined 55.7 MW total heat demand.

Fig. 1. Geo-localized heat demand: (left) SH demand; (right) DHW demand.

Fig. 2. Aggregated heat load curves for SH and DHW, hourly values (light colors) and daily values (dark colors).
3.2. Cooling demand

Annual values for cooling demand are derived from a survey of the authorization requests for centralized AC units in Geneva, over the 1980 – 2013 period [8], which contains GIS information, at building level, of the nominal thermal capacity, as well as the building category / usage type. In the case of the Jonction district, the 39 registered AC units totalize 8.9 MW nominal capacity (6.0 MW for comfort cooling, 2.9 MW for cooling of datacenter/telecom units).

Hourly profiles of these spatially aggregated demands are currently being reconstructed (work in progress), by re-scaling the aggregated annual cooling demand of the 16 MW GLN district cooling network [9], also situated in Geneva, for which hourly data of the various substations over 2015 was provided by SIG, the local utility company.

3.3. Electricity demand

Annual values for electricity demand of the Jonction district were provided by the local utility company, with distinction between residential and non-residential purposes (Fig. 3), totalizing an aggregated annual value of 114.1 GWh (18.6 GWh residential, 95.5 GWh non-residential), i.e about 4% of the total electricity demand of the Canton.

The hourly profile of this aggregated demand (Fig. 4) was reconstructed by downscaling the total Cantonal demand profile (2.9 TWh in 2015). For the Jonction district, the result of this procedure leads to an hourly peak value of 19.6 MW, respectively a daily average peak value of 15.5 MW.

At this point, the representativeness of the aggregated Cantonal load curve for a district dominated by residential and service categories remains an open question, which certainly speaks in favor of further studies, in particular for disaggregation of the diverse electricity usages.

![Fig. 3. Geo-localized electricity demand: (left) residential demand; (right) non-residential demand.](image)

![Fig. 4. Electrical load curve, hourly values (light colors) and daily values (dark colors).](image)
4. Local renewable resources

4.1. Meteorological and hydrological resources

As for the different demands, the local renewable resources are characterized in terms of hourly dynamic over the common reference year (2015):

- Meteorological data (solar irradiation, air temperature and humidity, wind speed, atmospheric pressure) are given by a nearby meteorological station [10].
- Temperature of the lake, at 35 m depth, is provided by SIG for the “Prieuré” fresh water pumping station.

The annual dynamic of the air and hydrological resources are presented in Fig. 5 and Fig. 6, in terms of hourly and daily average values (temperature and flow rate). While outdoor air is characterized by a high seasonal and daily thermal variability (hourly extremes of 3.8 and 37.5°C), the deep lake remains all year long at a fairly constant temperature between 5 and 10°C, except for short peaks of around 15°C, mainly in autumn, due to lake inversion phenomena [9]; note that these peaks could be avoided by pumping water some 10 m deeper [2, 9, 12]. In contrast, the Rhône River, which constitutes the outlet of the lake and represents latter’s superficial layer, has a similar seasonal profile to outdoor air, however with almost no daily oscillations; furthermore, due to the contact with the deep lake layers, in winter it never drops below 4°C. Finally, the Arve, which is an alpine river, is characterized by a nival regime with relatively cold temperatures even in summer. Its use for thermal purposes is further limited both in terms of suspended matter concentration (5 g/l under normal flood conditions and up to 10 g/l for important flood events [13] - which turns the use of heat exchangers extremely difficult), as in terms of uncontrollable flow rate (Fig. 6). On the contrary, the Rhône River is subject to a controlled flow rate, and contains little suspended matter.

Fig. 5. Temperature profiles for different resources, hourly values (light colors) and daily values (dark colors).

Fig. 6. Water discharge profile for Rhône and Arve rivers, hourly values (light colors) and daily values (dark colors).
Such hourly profiles can typically be used for characterization of the various resources in terms of expected HP system performance, as recently studied for the case of different types of multifamily buildings (new, retrofitted, non-retrofitted) [14].

4.2. Complementary information

As a complement to previous resource data, following GIS data has also been compiled [15]:
- Exploitable roofs for solar thermal or PV applications (roof surface, annual solar irradiance).
- Soil conductivity and capacity, for potential geothermal borehole applications.
- Environmental constraints (non-constructible areas, polluted soils, areas subject to flood danger) and space constraints (sub-surface constructions, tram trails, gas-, electricity-, telecommunication-, water-, sewage-networks), which may hinder the development of district heating/cooling networks.
- Noise limitations, which may hinder the use of air based heat pumps.

5. Conclusions

By compilation of existing data from various sources, combined with simple re-scaling algorithms, we set up a homogenous demand and resource database, comprising annual GIS-data, as well as district aggregated data (hourly dynamic over a common reference year).

The database should serve as a basis for evaluation of diverse strategies concerning the integrating of renewable resources in the particular existing urban district, and could be extended to the entire territory of the Canton. With availability of further basic data and/or in combination with models developed within the SCCER FEEB&D, the methodology could possibly be extended to the Swiss territory.

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References