Evolution of and additional functionalities to the city energy planning platform MEU

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Abstract

The MEU GIS-enabled web-platform has been developed in close collaboration with four Swiss cities: it enables detailed monitoring and planning for both energy demand and supply at individual building and neighborhood level (http://meu.epfl.ch). Whereas the first version of the MEU platform allowed launching calculations for only up to several hundreds of buildings at a time, the refactored version presently gives access to entire cities comprising several thousands of buildings with the same level of detail. On one hand, the code architecture has been thoroughly revised and consolidated while, on the other hand, the databases for the four partner cities are being completed, checked, corrected and eventually made completely available for several years. A large test campaign is thus underway on the refactored version of the MEU platform. In the upcoming months, the latter will present all the functionalities of the prototype version, i.e. include the construction and evaluation of complex energy scenarios.

New functionalities are concomitantly being added to the MEU platform, in particular at the level of the energy networks. Indeed, in the prototype version, the latter were only displayed but no network attributes (except geo-referencing) were neither introduced nor used in calculations. The envisioned new functionalities will enable to start filling this important usability gap by adding network detailed attributes to the database structure and by allowing pre-dimensioning calculations based on selected energy scenarios and including the networks characteristics (available power, temperatures/pressures, limiting dimensions, aso.). The energy supply side aspects will thus be quantitatively be taken into account, along with the implications in terms of network extension/densification precisely determined. The natural gas network, which is – and shall continue to be - broadly present in all four partner cities, representing up to 30 % of the overall final territorial energy consumption, will be used as the first test case, in close collaboration with local multi-energy utilities.

MEU platform – A tool for monitoring, planning and communicating

The objective of the MEU project [1] consists in developing and testing a web tool able to meet the needs of city and energy utilities engineers in terms of urban energy monitoring and planning. The project allowed fostering cooperation between academic partners, four Swiss cities – i.e. La Chaux-de-Fonds, Lausanne, Martigny and Neuchâtel – as well as the local multi-energy utilities – i.e. Viteos SA, Sinergy SA and Services Industriels de Lausanne. The tool has been thus built following the specs agreed upon by all partners, based on their operational workflow and concrete needs in terms of energy monitoring and planning, in a real-scale bottom-up approach. The platform presents the following main technical characteristics and functionalities:

- cartographic GIS-enabled interface as main working environment, with possibility to readily switch years (depending on available data);

- web-based platform fed by way of ArcGIS Server (ESRI) services;
- calculation of a complete set of energy-related and environmental yearly indicators for an urban zone at both building (demand) and supply levels, which can be displayed either as detailed tables or as maps and easy-to-visualize symbols;
- continuous monitoring on a yearly basis of detailed energy flows, aggregated and individual buildings consumptions, as well of the energy-related actions, by way of a temporal GIS-enabled database representing a faithful detailed energy picture of the city at any available year;
- step-by-step comprehensive approach to urban energy planning by way of scenarios directly created by the users – with typical user-friendly library functionalities -, on the basis of real data for a given year.

At the end of 2013, the project partners were presented with the first fully-functioning prototype of the MEU platform which essentially performed all foreseen functions. As explained below, an extensive refactoring of the prototype is currently underway, along with wide-range testing of both database consistency for all partner cities and addition of new functionalities.

The methodology behind all the energy calculations performed by the MEU platform is extensively presented and commented in [1-3]. The platform allows considering real energy consumptions down to the single building level up to city-wide aggregated computations. As outputs, the user can also compute primary energy global balances (which can be further sub-aggregated by services or by energy vectors), share of renewable energy sources and GHG emissions.

The MEU platform is particularly suited for interactions with political authorities, since it allows to get a detailed well-documented of the energy-related issues on a municipal level – leveraging on the cartographic view -, as well as detailed evaluations for future planning projects. On the other hand, the existence of a reliable database comprising all the energy-related data of a given municipality for any given year, enables new kind of relationship between cities and mandated consulting companies, leading to more appropriate and focused reporting. Finally, communication with public at large and with local stakeholders involved in city projects can be made more understandable and participative with upon using a GIS-enabled cartographic platform such as MEU. Experiences in this direction have been conducted in the involved partner cities with positive results.

One of the strategic future directions in which a tool such as the MEU platform could prove of fundamental importance towards a coherent management of energy-related data for an urban zone is the burgeoning field of smartcities [4].

Refactored MEU platform architecture

The software architecture of the MEU platform prototype was already very innovative and allowed to attain the specs imposed agreed upon among the project partners. However, the first prototype was clearly the output of a research- and not of a pure software development-project. Therefore, the former architecture displayed important flaws. A refactoring and consolidation of the platform code thus proved necessary in order to ensure operational stability and reliable performances to the cities and utilities.

A number of improvements have been implemented in order to ensure the robustness and overall reliability of the refactored application. These include test-driven development, domain-driven design, SOLID principles and an overall event-driven architecture. An enterprise service bus was also added in order to improve the scalability and failure handling of the platform.

As a result of these modifications, the coupling between all systems has been greatly reduced and a clear separation of all layers of code was made possible, see Figure 1. A Domain-Specific Language has been created, which – together with test-driven development - allows clear and testable specifications of the software's functionalities.

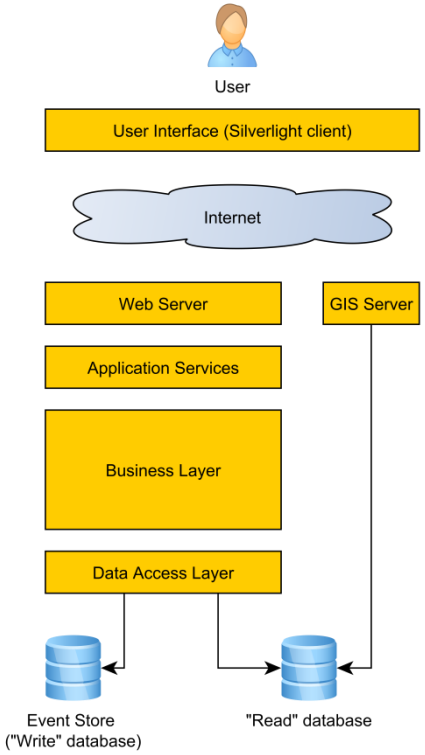

Figure 1 – Refactored architecture of the MEU platform

The improvement of the platform code is ongoing and further progress will be reported elsewhere. In parallel to code refactoring, the hardware infrastructure has been completely modernized with a dedicated server and all the ancillary services linked e.g. to data backup. A refactoring of the connections to the GIS services has been performed, while a dedicated phone hotline is also now available for the partner cities. Therefore, the MEU platform has undergone a huge step towards future possible commercial introduction, starting out from a research project led by academic institutions.

Pre-existing functionalities at a glance

The MEU platform is built along the following main structuring entities and concepts.

Buildings

City buildings represent the central element of the working environment of the platform, since they constitute the basic data node for storing energy conversion systems and their respective consumptions, on top of energy networks (see below). Indeed, the main functionalities of the platform are made available by way of the building footprint on the working map.

The physical and structural data of the buildings – including walls and windows parameters - is also stored [2] based either on default values depending on the construction year (imported from the Swiss Federal Registry of Buildings, RegBL) or on measured values entered manually by the user (e.g. following an energy audit).

Energy conversion technologies

In all the buildings, $n \geq 1$ energy conversion technologies are present and deliver $m \geq 1$ among the four basic energy services, namely space heating, domestic water heating, space cooling and electricity services. The distribution of services can be introduced manually or computed by way of CitySIM, a very detailed building physics software developed at EPFL[2,5] connected to the platform by way of a customized webservice.

The MEU platform offers a large spectrum of technologies, from heat pumps to various types of conventional boilers down to solar equipment and co-generation units, which can be fully characterized by the user. Decentralized energy conversion systems can also be taken into account, leveraging on the GIS functionalities embedded in the tool.

Energy consumptions

As far as they are made available – hence the importance of having multi-energy utilities as early project partners -, the yearly measured energy consumptions of each building are stored in the MEU database. For the buildings without measured consumptions, the tool will evaluate the energy demand (for each service) either by launching a simplified model based on the energy signature [1] or by importing and aggregating the energy demand computed by CitySIM. In the future, the user will be able to choose between the two methods which are clearly more adapted to different classes of buildings – CitySIM being particularly relevant for new energy efficient constructions.

Energy networks

Geo-localized energy networks – district heating, electricity, natural gas, free cooling, on top of non-energy networks such as fresh and used waters – can be added as additional maps to be visualized on the MEU platform. In the prototype version of the tool, these maps are completely passive, meaning that no network attributes can be visualized, nor any network-specific computation (i.e. balancing demand and supply) can be performed.

All energy vectors (both network-based, as well as oil or wood) are characterized by primary/renewable energy and GHG factors imported from KBOB database [6]. For network energies, network losses, as well as different supply contracts can be introduced and fully specified on the platform, in order to take into account the efforts of the energy utilities towards renewable energy sources and increased energy efficiency, e.g. on natural gas or district heating networks.

Energy current state of an urban zone

The data contained in the MEU database faithfully represent the current state of a given urban zone or of an entire city at a given year in time in an extremely detailed fashion. Indeed, if the data is collected and regularly checked over many years, the MEU tool allows precise monitoring of the energy demand and supply evolution over time, thus allowing city and utility engineers evaluating the concrete effect of the undertaken actions (such as refurbishments, networks improvements or even focused subsidy policies).

Indeed, the current state is one of the two working modes of the MEU platform and is conceived to be completely parallel to the scenario mode briefly described below (except for the read/write/delete/rename functions). The current state mode is used to visualize/modify data on individual buildings or citywide, either by way of symbolic maps or pop-up windows/tables containing all the relevant data/indicators. Metadata structure allows controlling data quality at any time by the platform administrators.

Scenarios

Scenarios represent another fundamental concept of the MEU platform. This term designates a state in which an arbitrary number of changes have been brought to the current state of an urban zone at a given year. Scenarios are built directly by the users and can be saved/deleted/renamed in a dedicated library directly accessible on the platform itself. Scenario is the second working mode of the platform. The latter gives access to the same functionalities as the current state mode, notably in terms of indicators. Scenarios allow quantitatively evaluating both demand- as well as supply-side energy plans in a very systematic and clear fashion. The user is enabled to compare current state for a given year and different scenarios, e.g. in order to evaluate the impact of foreseen actions.

New functionalities on energy supply networks – Towards a pre-dimensioning tool

In its actual configuration, MEU platform does not allow pre-designing networks depending on the energy demand of existing or future infrastructures, since natural gas, electricity and district heating networks are solely used for visualization purposes and are completely passive maps. This drawback of the prototype version implies, for example, that, within scenarios built by the users, buildings could be arbitrary connected to energy networks without any territorial, power or technology compatibility check. The amount of energy supplied by natural gas or heat networks in different parts of a city is generally available. However, additional useful information such as the maximum available power, pipes diameters, local flows or pressures, as well as heat losses and temperature levels are not available.

The idea is to create additional modules allowing testing of different pre-designed scenarios, in order to simulate the behavior of each scenario and to compute/display dynamic data on the considered network. The target is also to link high quality module of energy demand simulations with a new module aimed at dynamically simulating the behavior of energy networks.

There already are several commercial softwares such as NEPLAN® or WinFlow® that are capable of performing similar dynamic simulations and provide additional local data characterizing the energy networks. However, the cartographic display aspects of such softwares are not easily made compatible with the MEU platform code.

Representation of energy networks on the cartographic interface

Figure 2 shows a first cartographic interface prototype of the energy network module. The user would have access to several specification levels:

- Building specifications: building characteristics like the construction year and wall parameters; summer and winter power demand, aso.
- Pipe specifications: in-service date, diameter, peak flow, condition of the pipe, aso.
- Node specifications: inflows and outflows, schematic diagram of pipe's configuration, aso.
- Street specifications, with a view allowing summarizing data of a given street with the possibility to display the dynamic profile demand of natural gas: gas inflows, annual consumption of the street or the penetration of gas vector (number of buildings connected to gas network with respect to all buildings of the street), aso.

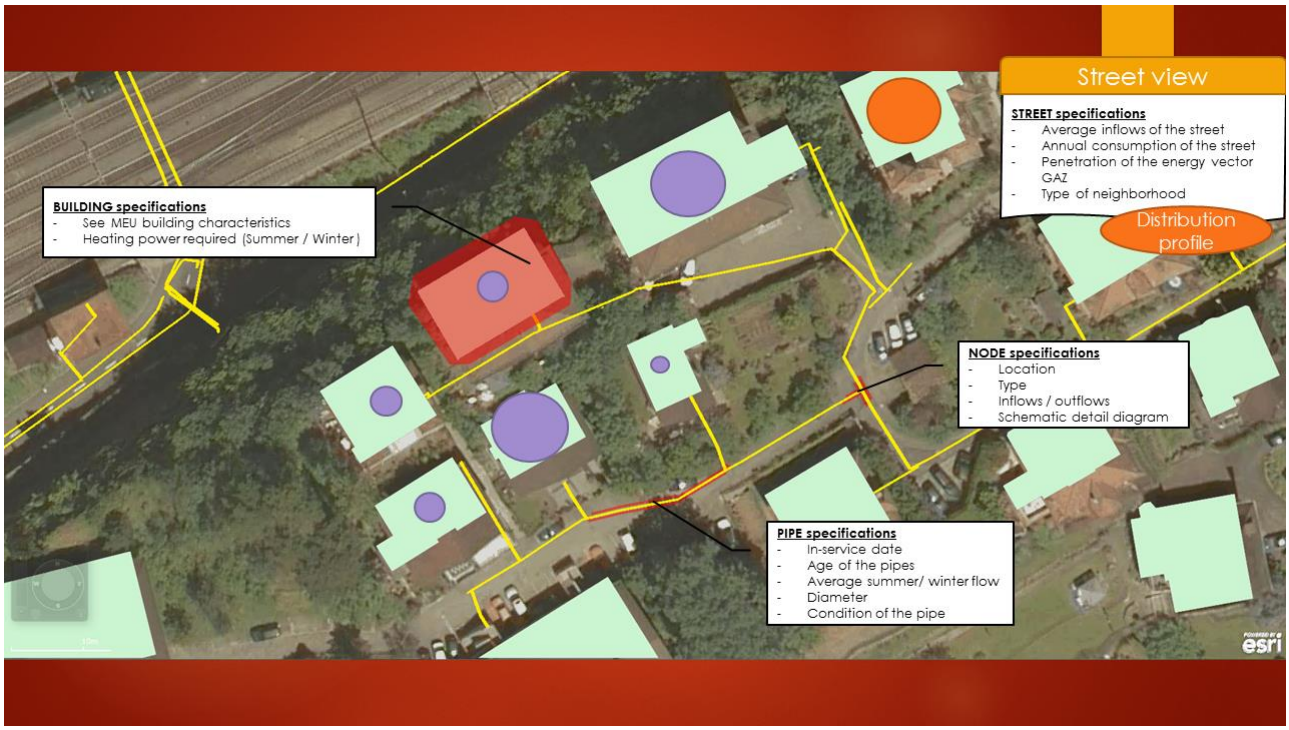

Figure 2 – Cartographic interface prototype of the energy network functionnality

Towards pre-dimensioning of natural gas networks on the MEU platform

We are targeting to create new functionalities for city energy managers and utilities engineers, in order to help them designing and expanding energy networks or for system monitoring purposes.

Users should be allowed creating new buildings, adding or deleting nodes and pipes, modifying installed heating power for an existing building and adding feed-in of biogas.

The resulting new network will be then tested and its behavior simulated to check matching between demand and supply and if the pressure is adequate in reducing stations to provide the natural gas to consumers along the line.

The network tool will be useful to determine if a new district can be connected to the existent network or if the actual network need to be densified. It will also help estimating the effect on individual energy supply of a missing pipe, e.g. due to road maintenance.

The simulation computation is based on a perfect and compressible gas model. The composition of network natural gas is considered to be pure methane. The model includes linear pressure loss equation and is built on the conservation of the molar flow rate through each node.

Houly data for consumed power are created via consumption profiles for each building using CitySim algorithms, while feed-in gas flow rates are determined from real data.

The studied system is limited to medium-pressure (< 5bar) and low-pressure networks (< 0.050 bar). Distribution pipelines in the range between 40 bar and 50 bar are not included in our model.

The simulation allows calculating pressure, molar flow rate and density of natural gas for every node of the network. Those raw results are then exploited and converted to graphics. The description of the network module is schematically shown on Figure 3.

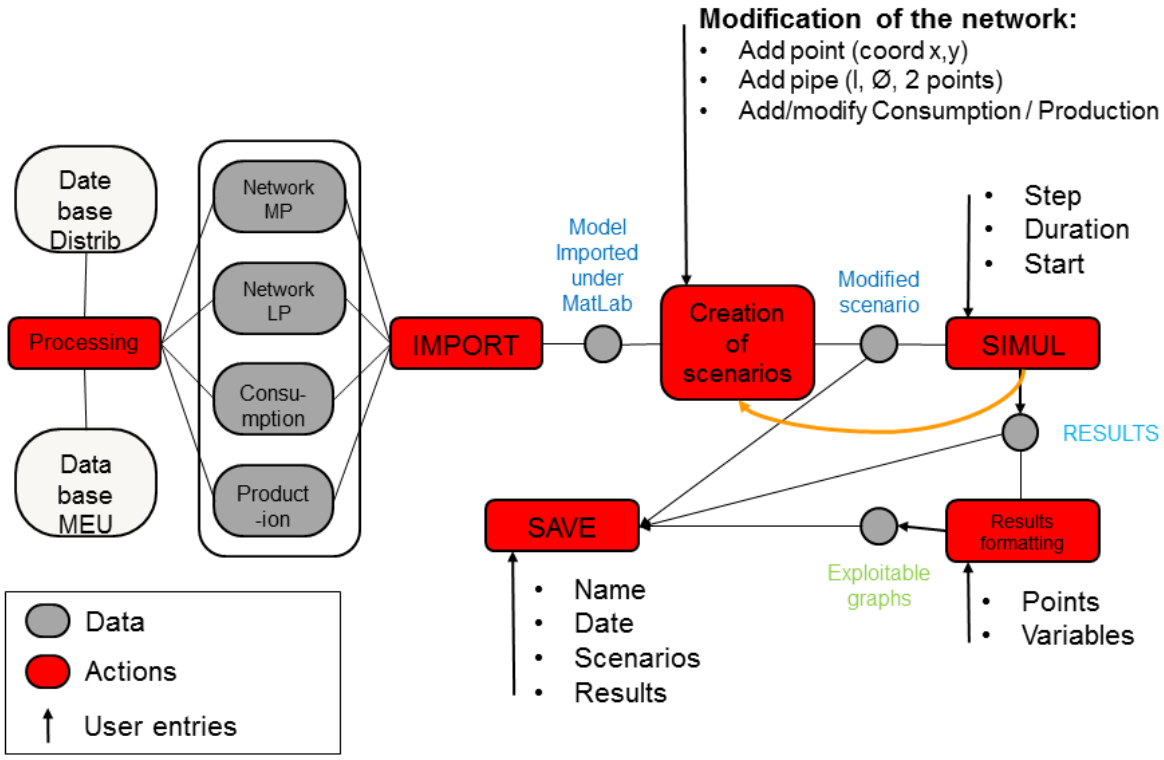

Figure 3 – Operational prototype : network module

Conclusions

Within the still ongoing MEU project, a comprehensive platform toward urban energy monitoring and planning has been developed and tested. The web-based GIS-enabled tool encompasses both energy demand and supply information of cities, relying on a robust database. It allows energy computations at the level of a single building, as well as aggregated citywide evaluations.

The MEU platform is presently undergoing broad code refactoring towards increases robustness and reliability. Concomitantly, new functionalities regarding the energy networks and in particular the natural gas networks, are being added. This will lead the MEU tool to be able to perform pre-dimensioning computations, further helping cities and energy utilities in their operations.

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