MEU – A cartographic-based web-platform for urban energy management and planning

Massimiliano Capezzali [1], *Gaëtan Cherix* [2],

[1] *Energy Center, Ecole Polytechnique Fédérale de Lausanne (EPFL), 1015 Lausanne (VD), Switzerland*

[2] *Research Center in Energy and Municipalities (CREM), 1920 Martigny (VS), Switzerland*

Abstract

This paper presents MEU (http://meu.epfl.ch) project results: a new GIS-centric web application for energy management and planning of existing or new urban zones. The project has been carried out with the collaboration of four Western Switzerland cities and three energy utilities companies using a "bottom-up" approach. The methodology involves the set-up of a dedicated geodatabase model aimed at structuring all energy-related knowledge of a city. Computation solvers could then be used to design and evaluate future energy scenarios. The ArcGIS Server-based web services are readily usable for cities in terms of data import, management, computation and display. The clear geographical presentation of computation results – for example on buildings' footprints thematic maps - using GIS functionalities and analysis tools facilitates the communication with all stakeholders at the local scale (such as energy utilities, local administrations, local government and the public) and provides figures to guide energy policy and investments. A complementary project on the monitoring of energy flows at a broader territorial level is also presented.

Contextual framework and objectives

Energy issues in urban zones have become considerably more complex in the last twenty years, notably because:

- new technologies penetrated the market and compete with fossil-based conversion systems;
- energy systems are evolving to systematically become multi-fluid and multi-services;
- cities worldwide have taken up a stronger and broader role in terms of energy policy and have committed to ambitious goals in terms of both increased energy efficiency and implementation of renewables.

As a consequence, cities and local energy utilities need increasingly sophisticated tools in order to both manage existing energy infrastructure and to develop planning strategies encompassing both demand and supply actions. However, such tools should be able to answer the challenge of addressing the complexity of urban energy systems and, at the same time, allowing to improve the communication towards policymakers, politicians, energy companies and broader public. The use of an effective GIS technology clearly represents a major element in realizing the latter requirement.

The MEU project aims at developing and testing a decision-helping web service which precisely answers the needs of urban energy and local utilities planners, in a direct collaborative framework putting together four Western Switzerland cities – namely La Chaux-de-Fonds, Lausanne, Martigny and Neuchâtel - along with research institutions and local multi-energy utilities – namely Viteos SA, Sinergy SA and Services Industriels de Lausanne. This tool displays the following features:

- GIS-enabled cartographic interface as main working environment;

- ArcGIS based web platform;
- quantitative computation of a whole range of energy-related indicators of an entire urban zone, either at the building/demand or at the energy supply level, including GHG emissions;
- access to completely hands-on planning of urban zones, by way of the creation and quantitative evaluation of scenarios encompassing desired improvements in terms of both energy demand and supply;
- continuous annual monitoring of energy flows, consumptions and related actions, such as building retrofitting or renewable energies integration, through a time-dependent database.

A first prototype of the MEU platform is presently being extensively tested based on real-case studies in the four partner cities. A broad effort towards the consolidation of the chosen architecture is concomitantly being pursued by the project team, leading to a robust and reliable tool for cities.

Web-based architecture

The ArcGIS web service-oriented architecture readily allows the addition of software modules on the MEU platform. The MEU geodatabase, implemented in postGRESQL, contains detailed information about buildings and energy supply systems; it thus possesses a remarkably broad potential range in terms of queries and indicators computation, going beyond the ones already implemented on the platform.

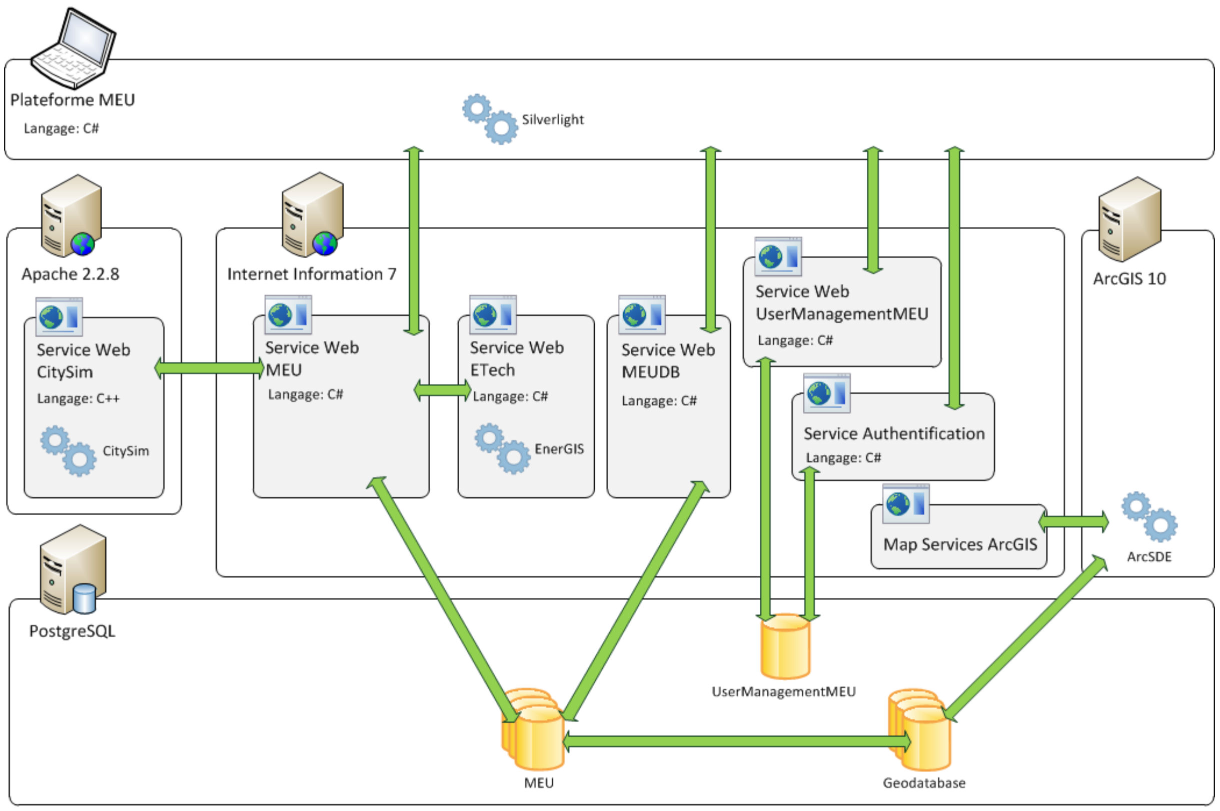

Figure 1 – MEU platform development architecture

The platform is developed using a WSOA (Web Service Oriented Architecture) architecture, see Figure 1, and is based on three distinct communicating building blocks, namely:

- the structured geodatabase;

- two solvers (CitySIM and E-tech, both developed at EPFL);
- the user interface (web);
- the MEU web service, entirely dedicated to the "orchestration" of the various services (database queries, solvers management, results processing and saving).

Main functionalities and display of the platform

The MEU platform and its functionalities have been built in a completely bottom-up approach, based on the requirements and concrete needs of the partner-cities and multi-energy utilities. The platform is based on the following main blocks:

Buildings

Buildings represent the central element of the platform, since it is through individual buildings that the energy demand and supply systems are defined, with the exception of energy networks. By clicking on a building, the latter becomes highlighted in yellow. The user has access to a rather thorough set of physical and structural data of the latter, including the possibility to update/modify the related fields, see Figure 2. The period of validity of the building data is displayed, along with the exact address.

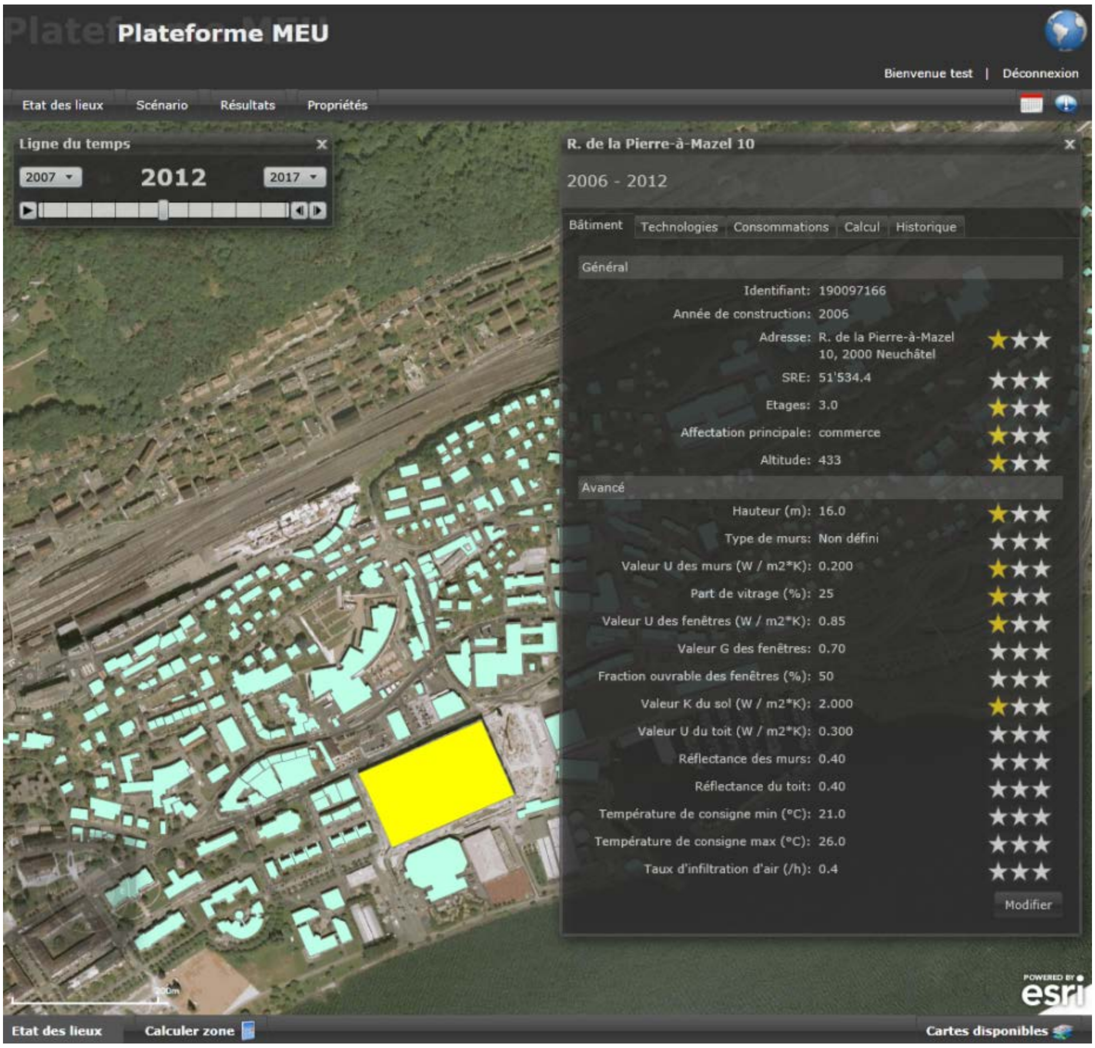

Figure 2 – Display of structural data of a selected building

The main MEU platform functionalities are accessed or visible by way of the footprints of the buildings (pop-up windows, display of indicators, aso.).

Energy Technologies

In each building, *n*≥1 energy technologies are present, fully or partially providing *m*≥1 out of 4 basic energy services, i.e. heat, sanitary hot water, cooling and electrical services. The platform offers a rather complete catalogue of energy conversion technologies – see Figure 3 - ranging from gas furnaces to different kinds of heat pumps and that can be fully characterized. The distribution of energy services supply can either be computed by way of a building simulation or manually.

In addition, centralized and decentralized energy technologies can be taken into account on the platform, leveraging on the geo-referencing of the energy conversion systems through their localization in one building.

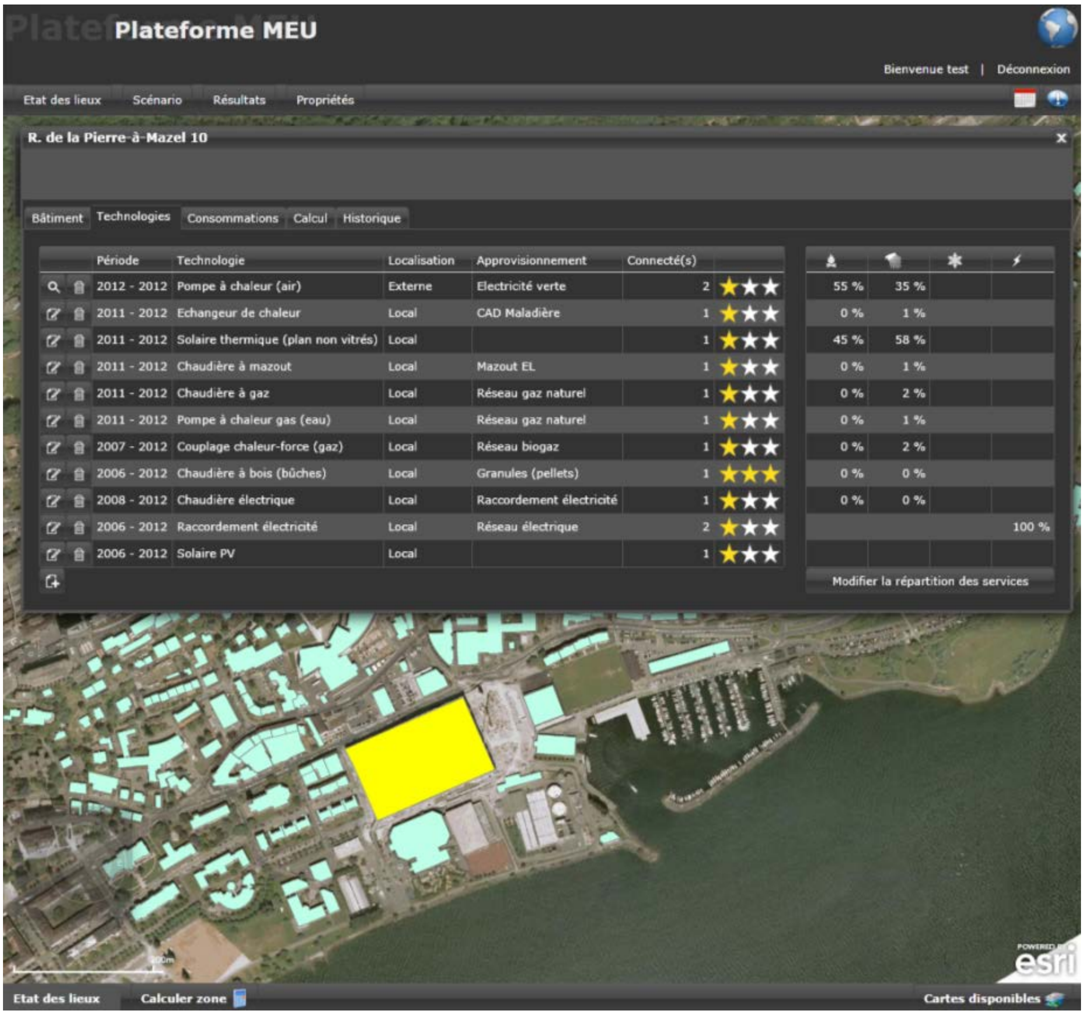

Figure 3 – List of technologies present in a selected building and energy services distribution

Consumptions

As far as possible, measured annual consumptions for each energy technology are introduced on the platform, see Figure 4. This proves to be fairly straightforward for network energies such as natural gas, but far more tricky for wood or oil-based energy conversion systems. In case real consumptions may not be available – notably in terms of the distribution by energy services -, the platform automatically computes simulated consumptions, using the CitySIM solver which is able to estimate accurately the energy demand of any building, taking into account its structural data, as well as the solar gain and the influence of nearby horizon.

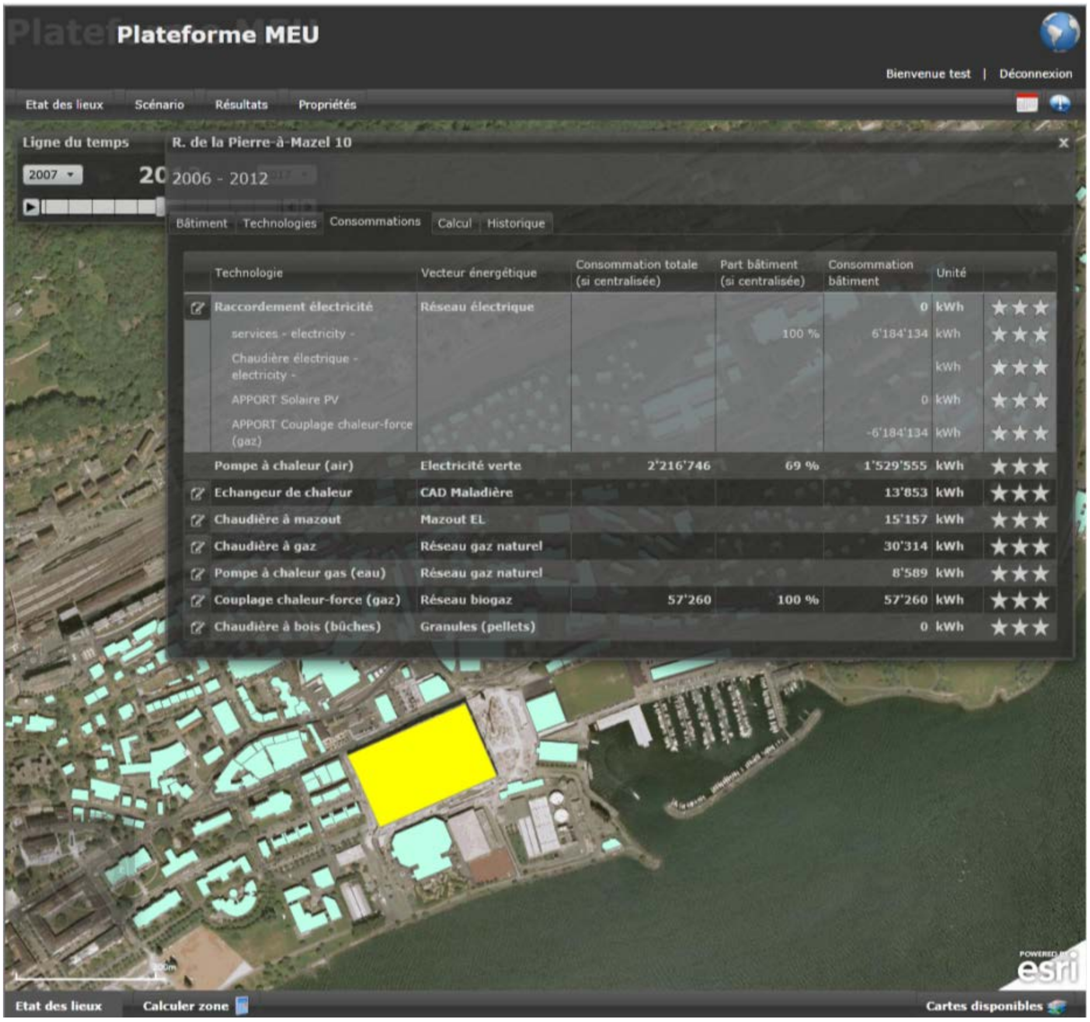

Figure 4 – Consumptions of energy conversion technologies present in a selected building

Networks

Geo-referenced energy networks – district heating, electricity, low- and high-pressure natural gas – can be added as a visualizable layer on the platform. This allows a cartographic overview of the present connections, as well as of the potential for future extensions. Further research activities are foreseen on a more thorough exploitation of GIS representation of networks, notably in terms of geometrical calculations and technical pre-dimensioning.

For the energy technologies requiring supply through a network, the latter can be characterized, notably in terms of primary energy distribution and in terms of GHG impact, by way of defining the existing customer contracts. This detailed definition allows to take into account renewable electricity contracts, biogas networks, as well as improvements related to the energy supply and overall efficiency of district heating networks.

Time line browser

A time line browser is available and allows to shift the data displayed on any active window in time automatically. The chosen granularity is annual.

Metadata

Each data introduced on the platform is additionnally characterized by a set of metadata. The latter allows to characterize the quality of the data – notably highlighting data that have been inserted as default and not as the result of a measurement and/or of an extensive simulation – and trace the user who saved/modified it, along with any other useful information on the data sources.

Energy state of an urban zone

Based on the above input information, the platform allows to get an extremely detailed overview and display of the current energy state of an urban zone (up to several hundreds of buildings) at any given year for which data has been introduced. In particular, a complete set of energy and GHG-related indicators are calculated. The latter can be either visualized on the cartographic environment or as aggregated result tables, based on an extensive menu for the user to choose from (Figure 5).

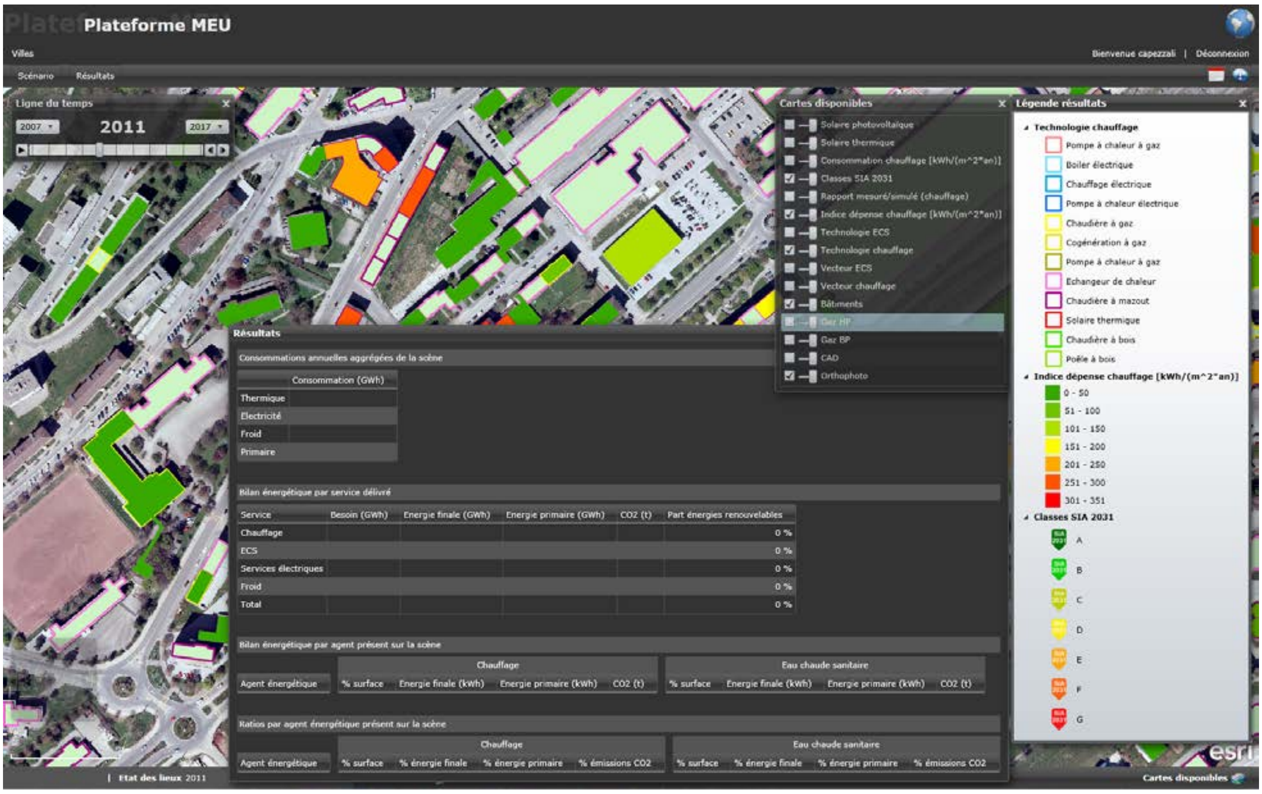

Figure 5 – Display of the current energy state of an urban zone

Scenarios

The central feature of the MEU platform is the possibility to modify any element of the energy state of an urban zone (at any given available year) in so-called scenarios. The tool then computes the whole set of modified indicators, which can be displayed in exactly the same fashion as the ones resulting from the actual energy state. Scenarios are intended to translate concrete urban energy plans and strategies – chosen directly by the cities and/or the local utilities - directly on the data characterizing urban zones and to allow a quantitative evaluation of their energy and environmental impacts.

Scenarios can be saved and modified by the user through a dedicated library. A clear visual separation between the scenario and the current state working modes is implemented on the platform, avoiding any potential confusion (see Figure 6).

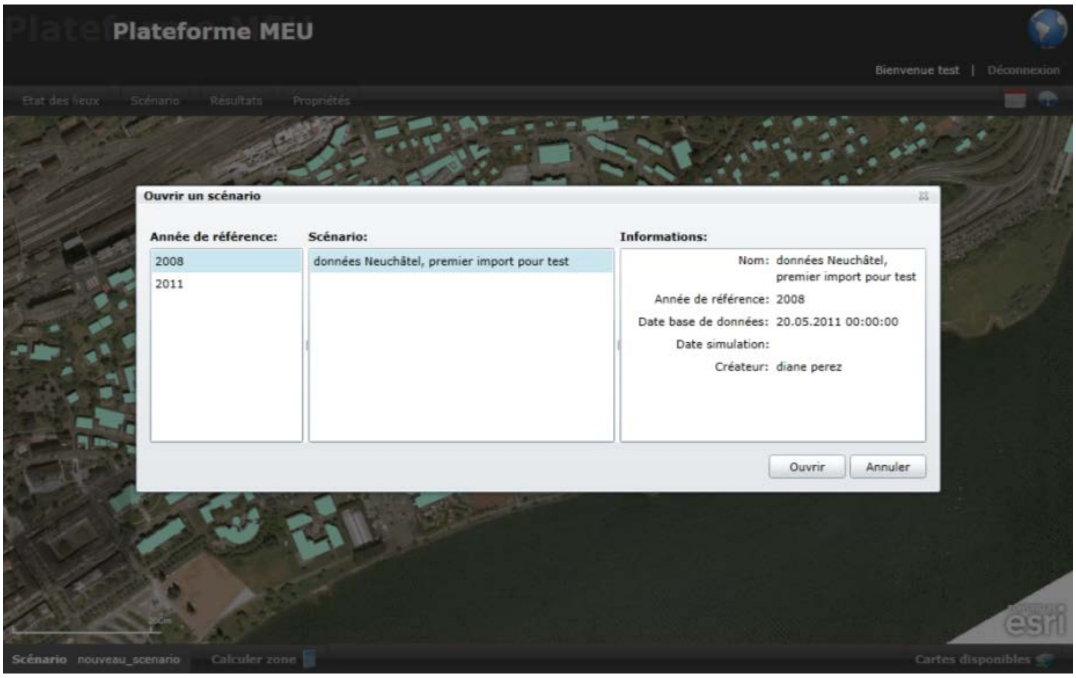

Figure 6 – Opening of an existing scenario, along with related information on its properties

Finally, the cartographic environment is particularly well-suited in order to gain overview of an urban zone in conjunction with the usage of various display forms for indicators. In parallel, this choice allows easy construction of future energy scenarios, with direct access to buildings and energy networks, and custom-made display of related computations or comparisons.

Energy flows monitoring at the cantonal level

In parallel to the MEU project, the EPFL Energy Center is also pursuing the development of a web-based tool aimed at visualizing the entire energy chain, from primary sources to end-use sectors at the level of a whole Canton (or territory). This project therefore broadens the scale and area of interest of the MEU platform – going from an urban zone to a far larger subnational geographic entity -, in order to create a complementary tool for decision support and monitoring, which centralizes all the useful information on energy sources, carriers and end-uses. This approach thereby gives access to a global overview, understanding and monitoring of the energy supply and demand characteristics of a given Canton.

The final goal of this recently launched project is to implement a platform allowing the direct visualization of all energy flows, thus translating and broaden the national statistics on the energy chain up to the cantonal level. Therefore, this innovative tool will allow to quantify primary and final energy profiles, to model conversion nodes in the energy chain, as well as to assess the overall energy balance per end-use sector or even per sub-entity of the considered territory: either a municipality, a district or the entire Canton.

The data inserted into the future wide database are to be updated automatically. The tool will be made available through a web platform to make the system permanently accessible to the users. The geo-referencing of the conversion nodes will allow direct visualization within a cartographic environnement.

Finally, the future tool will allow a very precise characterization and visualization of complex entities, from an energy standpoint, such as water-treatment plants or cogeneration units.

Conclusions

Through a bottom-up approach with four Swiss cities and the multi-energy utilities, a direct collaboration between territorial entities and the academic world has been established. The following features represent the major achievements of such a project:

- A software tool for decision support in the field of energy planning has been developed and is currently being consolidated.
- The MEU platform intends to answer the needs of cities through an interactive mapping approach and through the building of a data structure toward managing the energy complexity of an urban area.

The strength of this project lies in enabling cities and multi-energy distribution companies not to always resort to external mandates to assess the impact of energy development plans and/or retrofitting of urban areas. The platform will allow them to perform this strategic analysis work themselves, giving them the opportunity to compare scenarios and to address both demand and energy supply issues. Similarly, new regulatory frameworks can be evaluated in detail and their possible implementation be monitored over time.

In a broader albeit completely complementary approach, a new project has been launched with the aim to get a thorough view of the entire energy chain of a Canton (or any sub-national entity). The future web- and GIS-oriented software will provide a unique quantitative evaluation tool, encompassing energy sources, conversion systems and end-use sectors.

Acknowledgements

This work was supported by the Swiss Federal Office of Energy (SFOE/OFEN), the Research, Development and Promotion Fund of the Swiss Gas Industry (FOGA), the cities of La Chaux-de-Fonds, Lausanne, Martigny and Neuchâtel, as well as the Cantons of Wallis and Vaud. It was developed in collaboration with the EPFL Industrial Energy Systems Laboratory (LENI), the EPFL Solar Energy and Building Physics Laboratory (LESO-PB), the Research Center in Energy and Municipalities (CREM) and the University of Applied Sciences of Canton Valais (HES-SO Valais). The support and direct involvement of the multi-energy utilities Viteos SA, Sinergy SA and Services Industriels de Lausanne is gratefully acknowledged. The authors would also like to acknowledge the collaboration with ESRI for the use of ArcGIS Server.

Links and contacts

Additional information on both projects can be found at the following URLs:

http://meu.epfl.ch

http://speec.epfl.ch

Authors' e-mail addresses: massimiliano.capezzali@epfl.ch

gaetan.cherix@crem.ch