Open eQuarter

Research Report - Brief Paper -

Project: Sustainable and energy-efficient redevelopment of city quarters - Analytical and planning tools for energy assessment and rehabilitation of urban districts (Open eQuarter)

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Contents

1 Inducement and Ambition

The research project “Sustainable and energy-efficient redevelopment of city quarters - Analytical and planning tools for energy assessment and rehabilitation of urban districts (Open eQuarter)” is aiming at the development of a software environment to evaluate the energetic status of a block, a neighborhood, a city district or an entire city. The investigastion tool should calculate a set of geometric and energy-related parameters on building based precision with the lowest possible acquisition expense.

Furthermore *Open eQuarter* should facilitate predictions about the impact of

- taken measures in construction, building service und infrastructure,
- modification of supply structures
- social and/or economical changes as well as of
- political und conceptional objectives

on the energy efficiency of an investigation area. The *Open eQuarter* package should make use of a Geographic Information System and is supposed to be platform independent as well as free of charge.

*Figure 1.1: Investigation area *Open eQuarter* (VPT 2015)*

In line with the programming works a typical urban quarter was analyzed „by hand“. Scope and type of the inquiry were specified first and foremost by the needs of the software development. A complex 30 block quarter in Berlin’s district Neukölln was selected (s. Figure 1.1). With a typical urban structure and a variety of different building types and building ages it was estimated to be very suitable for development and validation purposes in *Open eQuarter*.

The „handmade“ quarter analysis and the programming work were closely coordinated to facilitate continuous information interchange between both fields of work.

2 State of Research

In most industrial countries there is a common political intent to produce and consume energy in an intelligent, anticipatory and resource-efficient way. Thus the development of energy-related evaluation-tools for middle- and large-scale settlement areas is gaining in importance. Different research projects of that kind were reviewed in the run-up to *Open eQuarter* regarding to their methods and the potential benefit for our project. Most of them made use of GIS in some way or another (Kaul et al. 2015).

Almost all of the reviewed research projects are focusing on evaluating and analyzing the building data of settlements as well as visualizing the results for further appraisals. The common problem of all these approaches can be found in the acquirement and the ascertainment of big numbers of building data. Two strategies are commonly used to avoid undue expense in this field. The first is to base calculations on the data of comparable quarters, the other is to classify the buildings by referencing them to an adequate typology and make use of the corresponding datasets. Both method have got their difficulties:

- The rigorous rules of classification end up in to a considerable number of cases apart. According to a first estimate for the investigation area of *Open eQuarter* in Berlin-Neukölln nearly a quarter of all buildings can not be classified appropriately.
- Extra building-specific information remains disregarded.
- There are no redundancy mechanisms uncovering and possibly remedying incorrect categorization.
- The development of detailed renovation concepts at least requires building specific information. In the light of experience this demand always necessitates a considerable number of additional investigations.
- Typologisation always means a loss of resolution. Thus subject to the degree of abstraction the results are getting more and more broad and universal.

Confronting this situation the development of a more precise and less laborious method for the acquisition of building data got one of *Open eQuarter's* maior topics.

Currently *Open eQuarter* is comprising a basic set of analytic tools, methods and scenarios. To push the open-source development of the project a simple application interface was defined in a way that third party programmers can easily extend *Open eQuarter* with additional acquisition and evaluation tools.

Open eQuarter delivers a database for an investigated settlement area consisting of data records for all recognized buildings. In medium term its results may establish a general, unique and multilateral public building database for all kinds of planning purposes.

3 Software Development

3.1 Requirement Analysis

As a first step the scope, the peripheral conditions and the resulting demands for the software development were determined. This included the identification of the relevant actors and stakeholders as well as inquiries about available equipment, used operation systems and software.

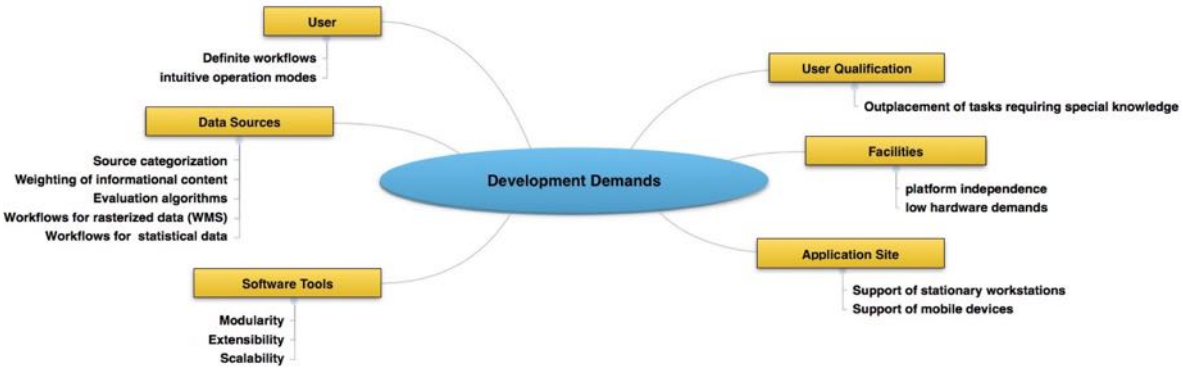

Figure 3.1: Demands on the Open eQuarter software (VPT 2015)

The demands for the development of *Open eQuarter* were narrowed down (see Figure 3.1) and the duties were split up into different fields of work.

Additional conclusions:

- *Open eQuarter* shall deal with redevelopment scenarios by repeating quarter investigations upon different conditions.
- *Open eQuarter* explicitly does not rate its investigation results. Having regard to all points it will still remain a question of human knowledge and experience to balance the economic, social, political and even esthetical needs and to finally draw the right conclusions.

All modules of *Open eQuarter* shall be published under an open-source license. By definition the complete package shall be free of charge.

3.2 Development Concept

Depending on the field of duty the educational requirements significantly differ. For usability reasons this got the crucial criterion for the work-area structure of *Open eQuarter* (see Figure 3.2). A common data storage (e.g. a database) is achieving the exchange of data and information[1].

[1] This solution makes sense as all possible users are connected to the internet.

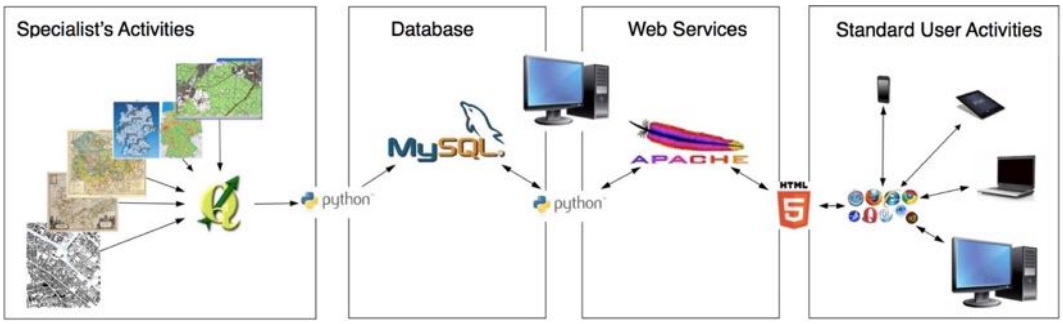

Figure 3.2: Basic application structure of Open eQuarter (VPT 2015)

A python based plugin for the open-source geo-information-system *QGIS* was developed to collect and process information from georeferenced sources. This plugin, called *Open eQuarter MOLE* is providing all necessary tools to the GIS-specalist, more or less automatically runs the building specific calculations and writes the results to a corresponding internal database.

These outputs are broadcasted to the central database (*Open eQuarter FOX*). They are now available platform independently for any purpose, e.g. algorithmic post processing or visual editing.

The client *Open eQuarter CROW* was defined as an HTML based online tool. That way the requirements on soft- and hardware of the end user are limited to an up-to-date webbrowser (Kaul et al. 2015).

3.3 Generic Building Parameters

In most cases time and labor to inspect a single building and file its energy-related dataset are acceptable. In contrast suchlike investigation of hundreds or thousands of buildings is getting an unsolvable problem considering time consumption and cost.

Thus the semi-automatic generation of energy-related building profiles from only a few initial characteristics and a bunch of free downloadable georeferenced sources evolved into one of the most important aspects of the project.

As a basic prerequisite for the development of *Open eQuarter* it was assumed, that a reliable energy-related outline of an investigated area could be provided even at a lack of detailed building information. Generic parameter sets gained by statistical research should be able to fill the gaps. At worst only the footprint of the buildings, some demographic benchmarks (e.g. population density) and the geographical position should be sufficient. Every additional building information will now state one or more of these average data more precisely. This way the body of source material only has effect upon the level of detail but not upon the evaluability of the investigated area itself.

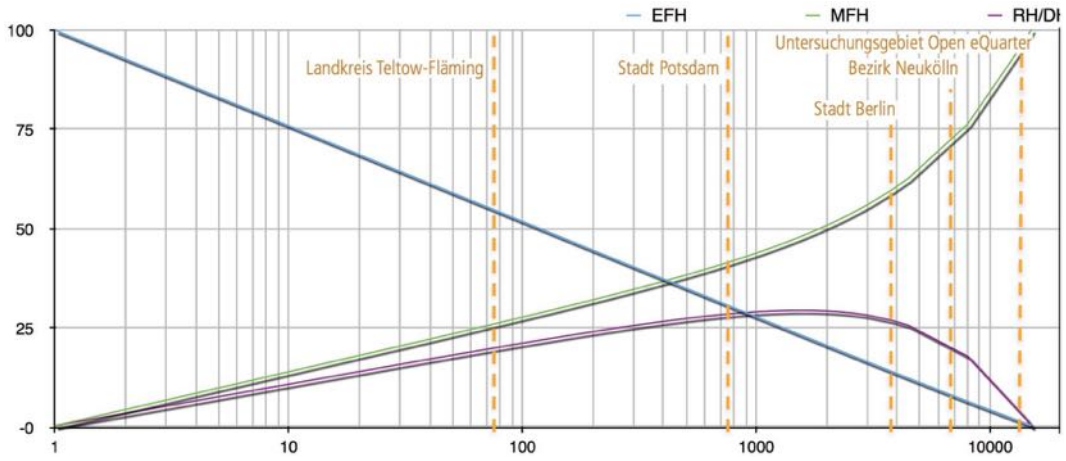

Figure 3.3: Distribution of residential building archetypes in % (EFH: Single Family Houses, MFH: Multi Family Houses, RH: Row Houses) subject to the population density in inhabitants /km2 (VPT 2015, Based on: Zensus 2011/Statistisches Bundesamt Destatis)

A number of region wide statistical surveys like the *Zensus 2011* (Destatis 2012), the IWU-Gebäudeindex (Diefenbach & Loga 2011) a.o. were reviewed and analyzed to find applicable correlations and to determine appropriate generic parameter sets. The found relationships were scrutinized and validated. Categorizations were replaced by determination equations where possible (Kaul et al. 2015).

3.4 Data Acqusition (Open eQuarter MOLE)

An important part of *Open eQuarter*, was implemented as a plugin[1] for the open-source geo-information-system *Quantum GIS*[2] called *Open eQuarter MOLE*. It is providing an extendable toolbox to acquire building data from georeferenced sources based on the methods mentioned above.

The acquisition concept crucially relies on the possibility to translate georeferenced raster graphics into numeric data. This type of sources for the most part is received from internet-based services. Thus apart from more obvious things like configurable color decoding functions it was necessary to implement some specific caching mechanisms as well. (Kaul et al. 2015).

The development of *Open eQuarter* is supposed to be continued by the open-source community. Aside from editing the source code for functional improvements, bug fixes etc. programmers and even experienced users can easily extend *Open eQuarter* by adding so called *Open eQuarter Extensions*. It takes only a few definitions and a core function written in pure *Python* to implement additional functionality. In fact all present tools for import, conversion and evaluation are only *Open eQuarter Extensions*[3].

Layered Information Acquisition (LIA) - The concept

Open eQuarter MOLE-plugin was designed to get as much building specific information from georeferenced sources as possible and deliver an individual dataset for each building of the investigation area.

[1] *Open eQuarter MOLE*
[2] briefly worded QGIS, see project page at http://www.qgis.org
[3] More details can be found in the project repository at http://modelica-buildingsystems.de/Open_eQuarter/

For this purpose a method called *Layered Information Acquisition (LIA)* was developed (see Figure 3.4).

First of all the quarter to investigate has to be outlined. *Open eQuarter MOLE* gives support by displaying a street map and by switching to the appropriate environment in *QGIS*. Now a „layer-stack“ (see Figure 3.4) is put together from two geographic references (“Building Outlines“ and „Building Coordinates“) and any number of information layers. They may be obtained from any georeferenced source[1] and imported by using the QGIS-toolbox or a content specific *Open eQuarter Extensions* of *Open eQuarter MOLE* (Kaul et al. 2015).

The result is representing the investigated land surface supplemented by an information scaled dimension (see Figure 3.4).

Needle-Request (NR) - Collecting building attributes

At that point collecting building specific data in *Open eQuarter MOLE* is quite easy. Figuratively a needle is attached right on the building coordinate of each building. Now the whole information stack is punctured at these points perpendicular to the surface. The properties found at the puncture points on the information layer’s (colors, attributes, areas, coordinates, descriptions etc.) virtually get stuck to the needles. The whole information block is now attached to the corresponding building coordinate object (*Needle-Request*)[2].

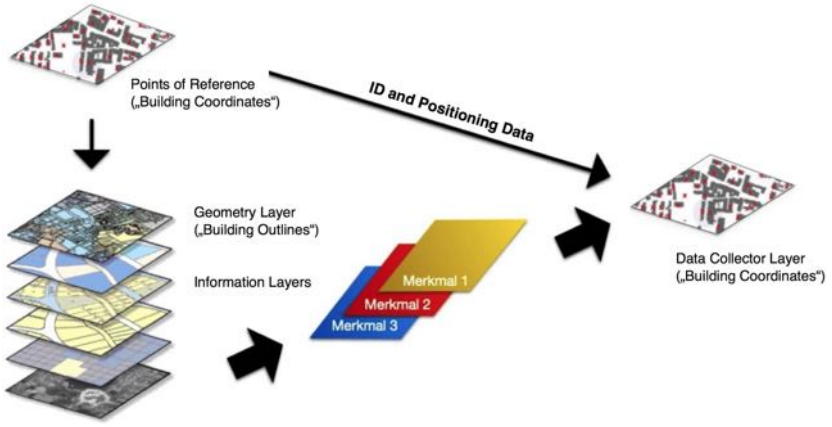

Figure 3.4: Collecting building information by Needle Requast (VPT 2015)

The collected attributes are now quantified by calculating characteristics as defined in source specific *Open eQuarter Extensions*. Finally the obtained building records are stored to the central database.

3.5 Database (Open eQuarter FOX)

Considering the latest development in the field of geo-database-systems - in particular the ongoing standardization regarding the Geographic Markup Language (GML) and the information model of CityGML - it

[1] E.g. CAD-files, image-files, data bases, tables, web-services, scans of paper maps or simple lists.
[2] The „Needle Request“ is handled by making use of the third party QGIS Plugin *Point Sampling Tool* by Borys Jurgie. See: http://hub.qgis.org/projects/pointsamplingtool

was decided to prepare *Open eQuarter FOX* as a generic data model instead of implementing a specific database system.

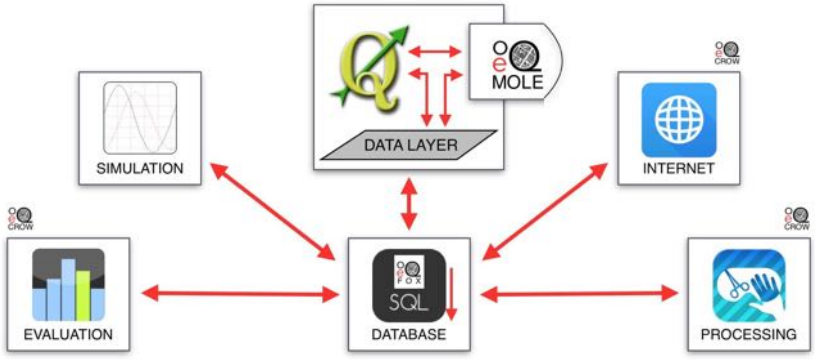

Figure 3.5: Data infrastructure for Open eQuarter (VPT 2015)

The acquired information and the evaluated parameters are temporarily stored on a dedicated layer using a simple attribute table. The arising building records are now transferred to data carriers or external geo-databases as required (e.g. a central SQL-database in Figure 3.5) by using export mechanisms provided by *QGIS*.

Open eQuarter is able to provide its results as geoJSON-, SQLite- und csv-files. Thus they are suitable for any kind of further treatment (see Figure 3.5) as well as for next steps in *Open eQuarter MOLE*. This includes possibilities to present or handle them on mobile devices by use of appropriate frameworks[1] as well.

3.6 Webfrontend (Open eQuarter CROW)

At a very early stage of the project it was agreed to use web-based communication features for the standard user interaction with the *Open eQuarter FOX* database. This way the standard user can easily deal with investigation projects - locally or remote - from viewing the results of *Open eQuarter MOLE* to defining energy-related scenarios through to reporting building data from mobile devices.

Within the scope of *Open eQuarter* a basic web application was developed to show the feasibility of a custom-made client as well as its abilities.

[1] like e.g. “openlayers” (http://openlayers.org) or “geoDjango” (http://geodjango.org)

4 Quarter Analysis

The development of *Open eQuarter* was accompanied by a classical survey of a typical Berlin quarter. The results turned out to be useful as a solid content-related reference for the implementation of *Open eQuarter* and for the final validation of parameters and methods.

The selected investigation area is part of the Berlin district of Neukölln. The typical blockwise structure as well as a wide range of building kinds and ages make it a perfect playground for testing and evaluating the tools of *Open eQuarter*.

4.1 Data Collection and GIS Data Management

The quarter analysis was based on the results available from previous investigations ((Hempel et al. 2010)). The inspection of this material was not only focussing on aspects of the urban structure and the energetic state of the reference quarter but on the availability of information specific geographic position data for further processing in a GIS. Considering the scope of checking and validating the methods of *Open eQuarter* as well as their results it made sense to collect the findings in likewise layer or database structures within QGIS.

These existing raw but georeferenced data were linked up with content specific information provided by different administration authorities and scrutinized in regard to topics like urban typology, building age, number of floors, building typology, building use, building state, supply systems, demographic structure, employment or ownership structure.

4.2 The Reference Quarter

The investigated reference quarter is located in the northern part of a redevelopment area at the north end of Berlin's district of Neukölln. The about 3 km^2 sized area is bounded on the north by the districts of Kreuzberg-Friedrichshain and Treptow-Köpenick. A remarkable spot can be found at the Sonnenallee. This arterial inner-city road is characterized by residential buildings with small trades in the ground floor. At the north the quarter is bordered by running waters like the Landwehrkanal and the Neuköllner Schiffahrtskanal.

The investigation area is inhabited by 30.663 people. 24.000 Inh/km^2 make it a populous city region. The site occupancy index is varying throughout the quarter around an average of 2,5.

12.522 people (about 40% of the population) are aged between 27 and 45, but only 10% are above 65. It is a young quarter with an above-average share of immigrants. The number of inhabitants subsisting on social welfare payments is staying over-average since years.

69% of the buildings are private property, 40% of these owners are in fact ownership communities.

Another 19% of the buildings are owned by housing companies.

The avarage rent of 7–8 Euro/m^2 is marking the lower end of rental fees at middle-class residential areas in Berlin. The purchasing price for condominiums is reaching 2.500 Euro/m^2 and stays slightly below the average level in Berlin.

The official standard ground value is listed as 410 Euro/m^2 of buildable area at a floor space index of 2,5.

Figure 4.1: Investigation area in Berlin-Neukölln (Based on Geoportal Berlin/ DOP20RGB 2014)

Most buildings of the quarter are residential. Pure trading (4%), public utilization (3%) or mixed usage (2%) are playing a minor role.

Most of the quarter's buildings are supplied by district heating. Unfortunately there was no information available about how the other buildings are heated. .

4.3 Cross Section Inquiry Fuldastraße

The final comparison of the results of *Open eQuarter* with the findings of the reference scrutineering did necessitate as much building specific information as possible. It was clear from the beginning that an evaluation in detail of all about 1000 buildings would not be achievable with reasonable expenditure. As a consequence a *Cross Section Inquiry* was carried into effect.

The challenge was to identify a street or a block series that is representing the investigated area as a whole in terms of building types and ages, of energy consumption and use as well as of demographic and economical aspects. Suchlike prototypical area could be found at the *Fuldastraße*.

The available previous investigations ((Hempel et al. 2010)) are including a remarkable range of building specific data. Additionally a close survey of each building was carried out to verify the given particulars as well as to close informational gaps. Dimensions were determined and relevant geometric parameters such as volumes and envelope areas were calculated from that. Kind and state of the envelope

components were recorded as well as information about the respective heating supply systems.

Figure 4.2: Window-wall ratio of facades at Fuldastraße 19-23 – Streetview (DMSW 2015)

Apart from construction attributes (e. g. Figure 4.2) the cross section inquiry covered the technical building services and supply utilities. Around Fulda- and Onckenstraße all classical heating supply systems of the 20th century can be found: central neighbourhood heating systems for ensembles of buildings, central heating systems for single buildings (driven by district heating, gas or oil), decentralized systems supplying single floors or flats (driven by gas or electricity) as well as outdated single room heaters (driven by coal or electricity).

The heat demand for the buildings was inquired from owners and property managers. Unfortunately only 20 of 62 interrogated participants returned utilizable data. The calculated average heat demand of 55 up to 153 kWh/(m^{2a}) (see Chapter 5, Figure 5.3, right) is not excessively high however not really representative due to the lack of cooperation on the owner's side.

5 Usability and Validation

To validate *Open eQuarter* the tools were employed on the area of *Fuldastraße* using different information depth. The results were compared to those of the cross-section inquiry.

Subsequently the findings of both procedures should be projected to the the whole reference quarter and finally revalidated in this larger scale.

5.1 First Experience

Using *Open eQuarter MOLE* upon a city section is quite easy and clear. The included *Workflow-Manager* is guiding the user though the investigation process step by step (Kaul et al. 2015).

5.2 Achievable Results

Open eQuarter MOLE's basic version[1] delivers a set of maps describing the energetic status of all buildings topic by topic. Figure 5.1 is showing the probable quality of the roofs (U-value) at the time of construction as well as what it would be like in our days if there were average renovation measures taken over the years.

5.3 Potential Error Sources

On different conditions systematic deficiencies were noticed during the trial operations. Their reasons could be recognized as a consequence of low quality sources:

- Imperfect georeferencing, effect: incorrect data collection while performing a *Needle Request (NR)*
- Coarse Categorization, effect: vague parameter calculation due to averaging
- Inconsistent building identification, effect: assignment of attributes and parameters fails

[1] Like data imports calculations are done by extensions. Even additional user defined evaluations may be included into *Open eQuarter MOLE* this way.

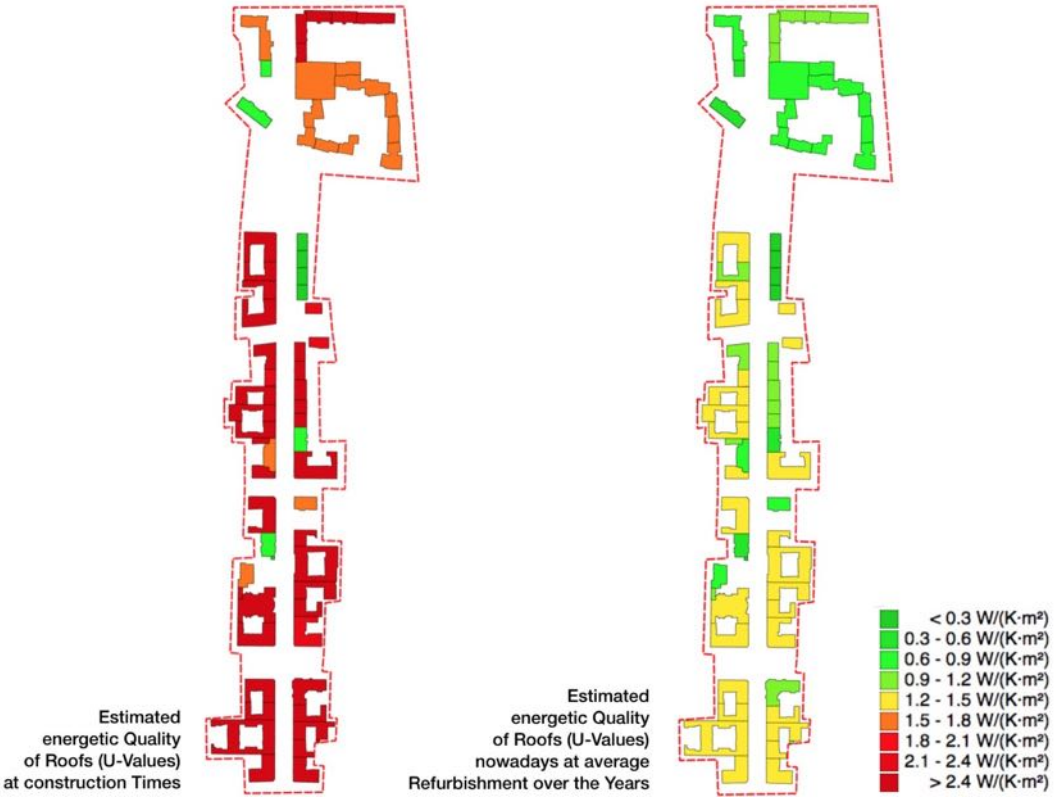

Figure 5.1: U-Values for the roofs of the investigated cross-section area (VPT 2015)

5.4 Validating the Cross Section Area “Fuldastraße”

To verify the reliability of the process the cross section area *Fuldastraße* was investigated by using *Open eQuarter MOLE* based on three or as the case may be four levels of root information. These levels differ by the number and the kind of the information layers only:

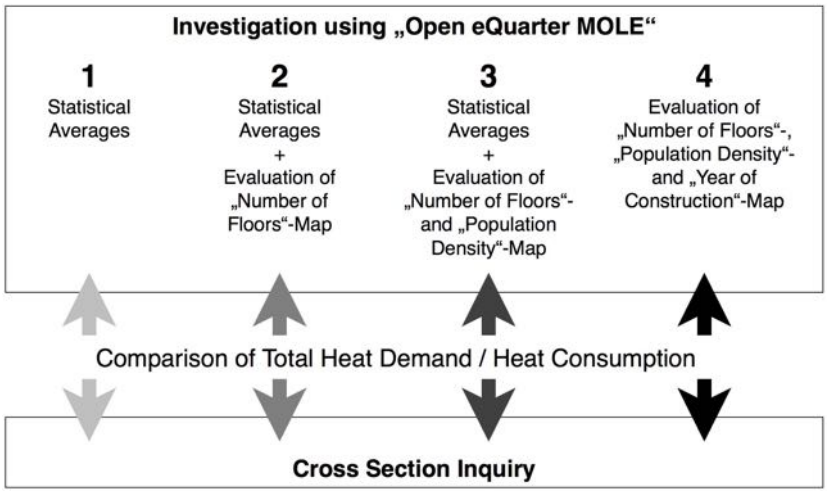

Figure 5.2: Validation method Open eQuarter (VPT 2015)

The thermal heat demand of each single building was calculated by *Open eQuarter MOLE* utilizing the methods described above.The results were juxtaposed in opposition to the found consumption data from the cross section inquiry.

Figure 5.3 is illustrating, how the results of *Open eQuarter MOLE* are changing when additional georeferenced information sources are taken into account. An investigation based on statistical data only (level 1) does not seem to fit the real consumption very properly. Including maps about the number of floors (level 2) and the population density (level 3) is each time considerably improving the results. The final consideration of georeferenced building age data (level 4) is bringing the outcome closer to reality again.

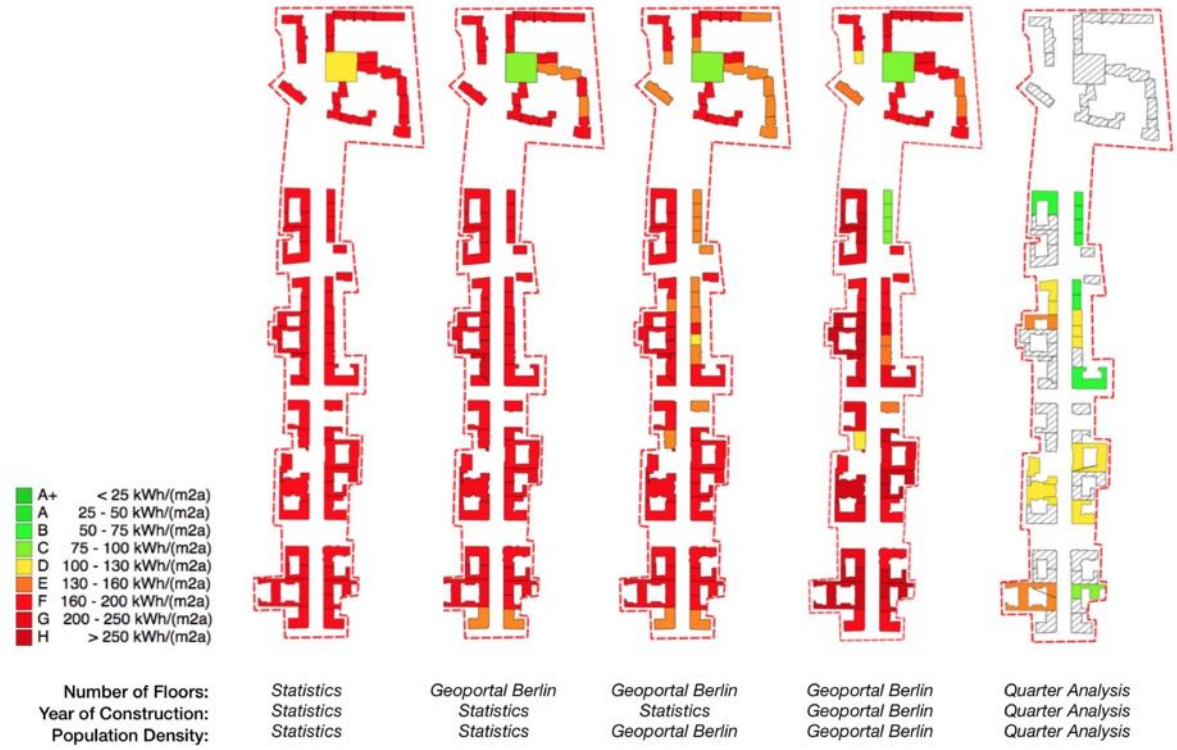

Figure 5.3: Heat demand calculated by Open eQuarter in comparison to the found heat consumption from the cross section inquiry (VPT 2015)

Despite the sophisticated effort of the cross section inquiry the found data remained very incomplete by the reasons mentioned in 4.3. Projecting the found results to the whole cross section area or even the total quarter did not appear to be promising. In contrast *Open eQuarter MOLE* was able to provide at least rough estimations even at the lowest level of information.

5.5 Employing the Tool to the Quarter

Subsequently *Open eQuarter MOLE* was employed to the reference quarter in Berlin Neukölln.

Figure 5.4: Heating demand by living area of all buildings of the reference quarter, calculated by Open eQuarter MOLE (VPT 2015)

As shown in Figure 5.4, *Open eQuarter MOLE* is able to provide nuanced results even based on only a few information sources .

The graphical representation in Figure 5.5 is conveying a good impression of how effectively the data acquisition methods of *Open eQuarter MOLE* can be used. Recognizably even moderate refurbishment can considerably reduce the total heating demand of the quarter. The area wide improvement of the component's thermal transmittance (base plate 0,6 W/m^{2K}, wall 0,8 W/m^{2K}, roof 0,4 W/m^{2K}, windows 1,2 W/m^{2K}) might achieve a decrease of 46%. After refurbishment the quarter's heat demand is estimated at 167.317 MWh/a instead of 310.118 MWh/a before.

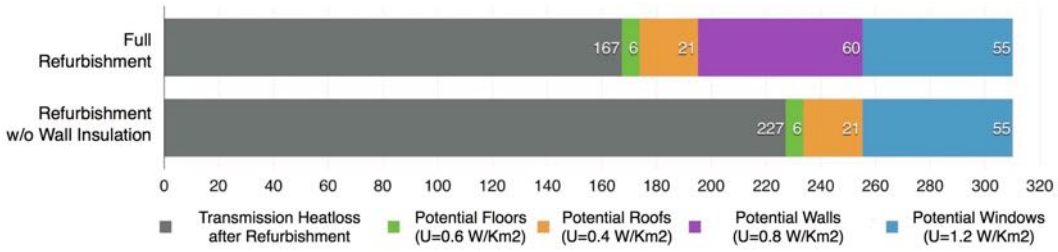

Figure 5.5: Improvement potentials in terms of the heating demand of the reference quarter at moderate refurbishment level, calculated by Open eQuarter MOLE (in GWh/a, VPT 2015)

According to Figure 5.5 the quarter might require remarkably less heating energy even without taking wall insulation measures.

6 Redevelopment Scenarios

Two scenarios of energy-related quarter refurbishment were drafted for testing purposes.

6.1 Scenario 1: Envelope Improvement and District Heating

The heat demand is supposed to be decreased by improving the energetic quality of the building's envelope. To ensure sustainable and considerate heating of as much buildings as possible district heating terminals are expected to be concentrated additionally.

6.2 Scenario 2: Envelope Improvement and Solarthermic Potentials

Like in scenario 1 the optimization of the building's envelopes is paramount. Subsequently the solarthermic potentials are supposed to be appraised as well as the options to implement a solar driven local heat grid including a common heat reservoir.

Figure 6.1: Transmission heat loss by living area HT' of all buildings of the reference quarter, calculated by Open eQuarter MOLE (VPT 2015)

6.3 Status Quo Evaluation

As a starting point the energetic state of all building of the quarter was established using *Open eQuarter MOLE*. Figure 6.1 is showing the output map referring to the living-area specific transmission heat loss H_T'.

6.4 Assessment of Pontentials

Both scenarios required energy-related improvement of the envelope components (Base plate 0,3 W/m^{2K}, walls 0,4 W/m^{2K}, roof 0,2 W/m^{2K} und windows 1,0 W/m^{2K}). It was assumed, that all buildings of the quarter are going to be refurbished.

The state after rehabilitation was calculated by *Open eQuarter MOLE* as a variant. Figure 6.2 is giving an example of an map output about the living-area specific transmission heat loss of the refurbished quarter.

Figure 6.2: Living-area specific transmission heat loss HT' of the refurbished quarter, calculated by Open eQuarter MOLE (VPT 2015)

6.5 Valuation

The recommended quarter-wide refurbishment for the testing scenarios would induce a remarkable decrease of the heating demand of the investigated quarter as a whole. *Open eQuarter MOLE* estimates it at about 125 GWh/a after rehabilitation, which means a decline of about 60%. Even without wall insulation the demand is getting reduced by about 31%.

Scenario 1: Expansion of District Heating

The potentials arising from the comparison of the initial and the rehabilitated situation for scenario 1 are visualized in Figure 6.3.

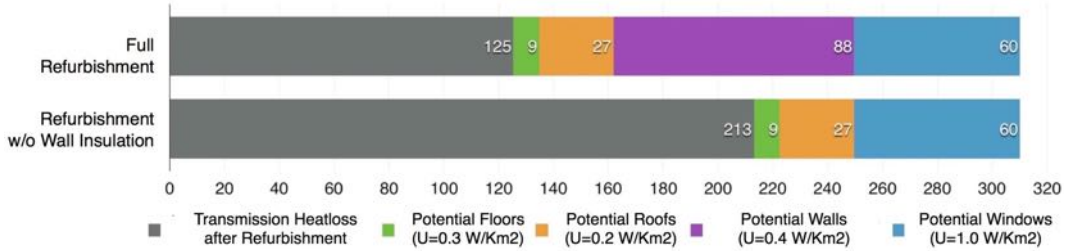

Figure 6.3: Refurbishment potentials according to the heat demand of the whole quarter, calculated by Open eQuarter MOLE (in GWh/a, VPT 2015)

The marked decrease of the heating demand down to two fifth of the original unburdens the consisting district heating grid. Thus even the existing infrastructure would be able to supply 2.5 times more buildings than before the refurbishment.

The development of the grid expansion itself nevertheless has to be carried out by using specific georeferenced sources about current pipe routings and building terminals.

By principle methods to route supply networks in an urban environment are suitable to be implemented into *Open eQuarter* as extensions. This functionality was not part of this project, but it may be an appropriate approach for future research activities.

Scenario 2: Solarthermic Local Area Grid

At the outset the available area for solarthermic collectors was appraised based on the eligible roof areas mapped in the *Solaratlas Berlin*. Unfortunately the authors marked out the whole area of every roughly flat roof as applicable. Such being the case a simple empirical calculation model was developed for *Open eQuarter MOLE* ((Kaul et al. 2015, 5.3.1)).

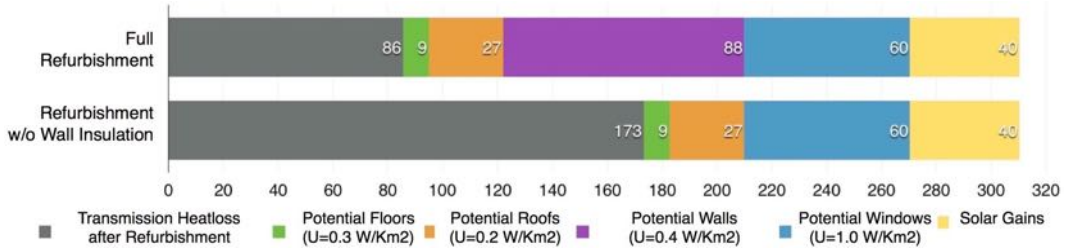

Figure 6.4: Refurbishment potentials according to the heat demand of the reference quarter including solarthermics (in GWh/a, VPT 2015)

Open eQuarter MOLE is predicting a 32% coverage of the heating demand of the reference quarter by a full-area solarthermic heat grid. (See (Kaul et al. 2015) for calculation details). Figure 6.4 is showing the comparison results referring to the energy-related potentials including the area-wide installation of

roof-mounted solarthermic collectors supplying a local area heat. *Open eQuarter MOLE* provides an output map about the solarthermic coverage rate as a maximum for each building (Figure 6.5).

Figure 6.5: Solarthermic coverage rate by building, calculated by Open eQuarter MOLE (VPT 2015)

It has been demonstrated that *Open eQuarter MOLE* is able to provide estimations about the roof area available for solar use, the living area to be heated, the building geometries and the energetic quality of the buildings and their components at different states of rehabilitation. Thus it can deliver valuable evidence for the development of a solarthermic local heat grid right up to the storage planning.

Open eQuarter's priority objective was the development and implementation of a new method to acquire and analyze georeferenced information in a *GIS-Environment*. Thus calculation modules for e.g. redesigning heat grids with due regard to concurrent infrastructure like waste water, power lines, fiber optic cables etc. have to be part of the further open-source development process.

7 Conclusion

Open eQuarter is bringing new facilities for investigating and evaluating city quarters from an energy-related point of view. Using *GIS* allows *Open eQuarter MOLE* to acquire information from any kind of georeferenced source. It has been demonstrated, that the concept of geographical superposition of these sources *(Layered Information Akquisition (LIA))* and a subsequent *Needle Request (NR)* are applicable to generate a complete information base of a quarter on a building scale.

Obviously the quality of the results is depending on the catergorization's granularity and the georeferencing precision of the selected sources. In larger scaled contexts and in terms of a standardized data exchange there it lacks in a solid and generally accepted method of generating worldwide-unique building IDs.

7.1 Statistical Generation of Generic Input Data

By reviewing and evaluating a large amount of statistical data of the Zensus 2011 (Destatis 2012) and studies for a „National Building Typology“ by the „Institut für Wohnen und Umwelt“ (Diefenbach & Loga 2011) correlative relationships - e.g. number of floors of a building as a function of the population density at its location - could be identified. A second class of parameters was found that showed dependencies in principle, but could not be traced to a functional connection. This behavior predominantly is pertaining parameters that are sensitive to historical incidents and economical conditions. The link between heat transfer coefficients and building age for example is getting deranged by the world wars. Parameters of this class were correlated by using lookup tables.

By this approach *Open eQuarter MOLE* can provide differentiated results even at a lack of dedicated data. The minimal set of information consists of building geometry, number of floors, building age and population density.

7.2 Connectivity and Interactivity

To give an impression of the communication facilities of the concept, a very basic, mobile-suitable web client was developed. It can be used to view all collected geo-information, the calculated building parameters and its characteristic values as well as the quarter specific results. Other fields of utilization can be found in the interactive generation of variants or in the gathering of building data on a mobile device.

7.3 Open-Source Concept

The open-source concept of the project is aiming on a proceeding development within the GIS community. To promote this approach an *Open eQuarter Extension system* was implemented. It is providing a

simple interface enabling users and developers to expand the functionality of *Open eQuarter* with only a minimum of programming work. All imports and exports as well as analyzing and evaluation functions within *Open eQuarter MOLE* are performed by this type of dedicated expansion modules.

The details and all sources can be found in the project repository at http://modelica-buildingsystems.de/Open_eQuarter/.

7.4 Quarter and Cross-Section Analysis

The project was supported by a conventional quarter analysis and a cross-section inquiry. Numerous sources of georeferenced information were reviewed and investigated regarding their suitability for use with the *Open eQuarter MOLE-plugin* under *QGIS*. The application to the reference area did provide a profound representation of the energetic state of the quarter in Berlin Neukölln (see Chapter 6.2). Apart from aspects of urban planning as site, utilization, building constructions or building age structure a good estimation of different energy-related features (e.g. type of energy supply for heating) could be acquired. In addition demographic and economical factors as kind of ownership or inhabitant's age structure were scrutinized.

The final comparison of the results of *Open eQuarter* with the findings of the reference scrutinering did necessitate as much building specific information as possible. It was clear from the beginning that a detailed evaluation of all of the about 1000 buildings would not be achievable with reasonable expenditure. As the „Fuldastraße" is picturing the situation in the quarter to a great extent, a *Cross Section Inquiry* was carried out for that street. As a result an assessable amount of building specific data was pieced together (see Chapter 4.3).

The „manual" analysis of a reference quarter performing a *Cross Section Inquiry* in parallel with the software development turned out to be a worth-while supplement for the conceptional work. On one hand the on-site investigation could be adapted to implementation and validation needs. Vice versa the findings in the reference quarter gave important contextual impact to the design of the software solution.

7.5 Variant Evaluations

Open eQuarter is able to achieve the investigation of settlements on different scales. Based on this refurbishment variants can be simulated by varying relevant key parameters. As an example in the project two scenarios were played though for the reference quarter. The first approach consisted of a refurbishment of the building envelope including the expansion of the district heating system. The other was supposed to give estimates about the performance of a solarthermic injected local area heat grid if a refurbishment of the building envelopes was carried out before.

7.6 Expenditures

The *Cross Section Inqiry* of „Fuldastraße“ took about 140 man-hours or rather 17 man-days of work for all 70 viewed buildings. Unfortunately the result stayed incomplete despite the effort. In contrast the use of *Open eQuarter MOLE* provided a first complete and nuanced output after roughly 1 hour.

Scaled to the whole reference quarter the“manual“ inquiry would require about 1.900 man-hours or rather 237 man days at a gappy outcome. *Open eQuarter* had to achieve this job in the course of evaluating the test-scenarios. It took about 2 hours of preparation work and roughly 5 hours of computation time depending on the used hardware, all in all about 1 man day.

Presuming the minimum net wage of 8,50 Euro per hour in Germany, which means about 15,50 Euro as total costs, the financial comparison looks like this:

- Conventional quarter analysis „by hand“:
  - 3100 Euro /100 buildings
  - gappy outcome
- Investigation by *Open eQuarter*:
  - 11,50 Euro /100 buildings
  - complete building database

The detailed estimates even on a brief body of source material at a minimum of time consumption designates the use of *Open eQuarter* as an economically advantageous method for the quarter analysis compared to its competitors. (see Chapter 2.1).

7.7 Perspective

It can be stated, that a further development of *Open eQuarter* appears to make sense. Regarding to the open-source context different fields of work are arising:

- Further evaluation of statistical sources targeting on identifying additional reliable corellations
- Implementation of additional *import-Open eQuarter Extensions* to increase the range of utilizable kinds of sources
- Implementation of additional *operational Open eQuarter Extensions* for analysis and evaluation
- Adaption of additional geographic data formats with a view to upcoming standardizations like e.g. CityGML
- Further development of *Open eQuarter’s* web client technology to offer the full range of interaction capabilities.
- Further validation by comparison to larger, already investigated and well documented planning areas

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