Refurbishment of building envelopes on a district level

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Abstract

Article presents advantages and options for renovation of buildings, which appear when we approach the refurbishment process on a bigger level – district level. This approach is being investigated in the scope of the EU program - Horizon 2020 within the project called MODER.

Project MODER tackles mobilization of innovative design tools for refurbishment of buildings on a district level. In this aspect, different tools and measures are being evaluated. Regarding building envelopes, we evaluated thermal insulation, and installation of appropriate windows in various European countries.

Scope of the project exceeds common measures on buildings (facade refurbishment, installation of solar panels, shading and use of renewable energy sources for heating and cooling). Article presents some of the advantages that derive from refurbishment of building envelops on a district level, tools we need, and can already be used, and gives some insight in the business models that need to be formed, validated and used.

Tools that are being developed in order to help with decision-making process and visualization of measures of district refurbishment are D-ECA tool (District Energy Concept Advisor – developed by Fraunhofer IBP), and 3D visualization platform (developed by VTT).

Keywords: refurbishment, district, energy savings, cost savings, business models, tools.

1. Project MODER

Project will develop, demonstrate and mobilize design tools, processes and business models for efficient refurbishment on a district level. Design tools will enable evaluation of different retrofitting alternatives at different stages and scales, simultaneous consideration of cost and energy efficiency. We are also aiming at sustainable retrofit design by developing models for procurement and models for design management. Business models focus on finding connections and business opportunities for stakeholders involved in the refurbishment process, and thus encourage and contribute to increase in numbers of district refurbishment across Europe.

The interplay between supply and demand brings important challenges to designing and managing of nearly zero energy buildings (nZEBs). The annual energy consumption of buildings can be decreased with the help of different measures of energy-efficient renovation. However, at the same time the consumption of electricity and electricity peak loads may increase (use of heat pumps, electric cars, etc.). Thus, when renovating districts, we have to consider that distribution grids with a large number of Net Zero Energy Buildings have to be designed for managing both loads and generation. This can cause mandatory reinforcement of grids or other solutions to grid management that come with a cost for the grid operator and/or the customers [1].

1.1 Main goals of the project

Quick overview of goals of project MODER

- Development of tools for design at district level that enable comparison of various alternatives of RES systems.

- Promotion of the simultaneous consideration of energy and cost savings to improve the interest of owners and users in participation and decision-making.
- Improvement in understanding of the behaviour of complex energy systems for non-technical stakeholders by visualization to give an easy-to-understand access to alternative energy scenarios.
- Development of processes, and practices that enable building owners to activate refurbishment at district and neighbourhood level.
- Development of business models for engineering companies, consultants and energy managers MODER will promote integrated project delivery models needed in refurbishment at district level.

1.2 Partners working on the project

MODER is an international project that joins 10 partners with vast amount of knowledge and experiences, coming from six European countries. List of partners working on the project.

- **Sweco Finland Ltd., Finland**
- Teknologian tutkimuskeskus VTT Oy - VTT Technical Research Centre of Finland Ltd., Finland
- Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung EV - Fraunhofer Institute for Building Physics IBP, Germany
- Siemens AG, Germany
- REM PRO SIA, Latvia
- Stichtung W/E Adviseurs Duurzaam Bouwen - W/E Consultants Sustainable Building, Netherlands
- Ertex Solartechnik GmbH, Austria
- Gradbeni Institut, ZRMK DOO – GI ZRMK, Slovenia
- FinnEnergia Oy, Finland
- Lokalna Energetska Agencija Gorenske Javni Zavod - LEAG, Slovenia

1.3 Acknowledgements

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1.4 Advantages of refurbishment on a district level

MODER project assessed the basic opportunities for profitability and minimization of costs in energy-efficient refurbishment projects at district level.
Renovations can have different scales. From building, neighbourhood, to district level. Common goal of stakeholders in the project should be minimization of costs of refurbishment. Looking from owners viewpoint main issues are the size of investment, maintenance and energy cost savings and quality of living conditions.

Building renovation of envelope (insulation of the envelope and renovation of the windows) will increase the quality of indoor environment, it will reduce energy usage and CO2 emissions. However, looking from an energy efficiency point of view, it would be advisable to refurbish entire residential districts together with heating, cooling, water and waste infrastructure. This is the only way of ensuring that the building-specific measures aimed at improving energy efficiency would also affect the entire residential district and its energy production, and thus efficiency and utilization of RES. If the renovation is limited only on individual building, that particular site may save energy and water, but the measures will not necessarily have any impact on the energy production and water needs within the district [2].
Big
District level refurbishment has clear benefits from residential point of view (certainty and improved energy efficiency, reduced emissions throughout the energy chain, better living conditions, shorter total refurbishment process – less disturbance, etc.). District renovation approach could also be very interesting for companies (bigger project, prefabrication, energy distribution, etc.). All this would mean lower cost of tendering process, planning and construction. Renovation on a district level also opens few new business possibilities and challenges that arise from bigger scale of the project and optimization of NZEB (production of systems for renewable energy generation and storage, monitoring, automatization and optimization of processes, synchronization of consumption and generation, load matching, grid interactions, etc.).
Furthermore, due to a large percentage of old buildings in Europe, many buildings are in poor conditions, and therefore in need of renovation. Comparison of building renovation on one side and demolition and

reconstruction on the other side shows that refurbishment except in extremely deteriorated buildings a better solution (from financial and ecological point of view).
When planning building refurbishment several key groups of measures are recommended for deep renovation:

- Insulation of exterior walls (additional insulation if insulation is already in place).
- Installation of energy efficient windows.
- Improvement of electrical and mechanical installations (heating, cooling, ventilation, etc.).
- Automation, proper management and regulation of smart grids in the district.

Deep renovation projects can have remarkable improvement in energy efficiency, but also oppose several economic barriers, which include high initial capital cost, long payback periods, subsidized conventional energy, and lack of incentives for decentralized RES systems. However, refurbishment on district level may offer a way to reduce risks and improve benefits. This requires that that the project is able to utilise the most potential ways to develop the district and improve the attractiveness, user-value and energy-efficiency of individual buildings. It is estimated that total costs of group construction (€/m²) are 5 - 15% lower than in the case of individual buildings

IEA EBC studied profitability of energy-efficient refurbishment on a district level [3]. Based on the results improved energy efficiency has an important effect on the tenants' improved quality of life through increased comfort, increased neighbourhood security and increased sustainability of housing. Although energy conservation measures in most studied cases resulted in higher capital investments, the total monthly costs for rent and purchased or operating energy for tenants are often the same or only slightly higher. Additionally, building owners reduce their risk and benefit from a more predictable Return on investment. All studied case projects resulted in large reductions in both primary energy use and greenhouse gases emissions. The revitalization costs in the cases analysed by IEA 51 were typically 80% of new development costs though there were rather large deviations. Investment costs ranged between 1,200 and 1,400 EUR/m² for ambitious revitalization to low-energy standards and complicated planning contexts. For less ambitious modernization, the anticipated costs would be between 800 and 1,100 EUR/m². The total costs can be outlined to the following cost categories (maintenance, modernization, energy conservation and energy use measures on a building level, energy supply-related measures).

Table 1: Comparison of costs between individual and group refurbishment*

Measure/action	Unit	Existing condition	After renovation (individual building)	After renovation – (group construction)
Additional insulation of base floor	U –value [W/m²K]	0,35	0,17	0,17
	Construction cost €/ap-m²	/	15 - 25	12 - 22
Additional insulation of exterior walls	U –value [W/m²K]	0,45	0,15 - 0,17	0,15 - 0,17
	Additional cost €/wall-m²	/	120…160	100…140
Additional insulation of roof	U –value [W/m²K]	0,5	0,1	0,1
	Additional cost [€/roof-m²]	/	20 - 30	17 - 27
Choice of energy efficient windows	U –value [W/m²K]	2,5	0,6	0,6
	Additional cost [€/window-m²]	/	80 - 90	70 - 80
Sealing of building envelope	Air-density	q50≥4 1/h	q50<1 1/h	q50<1 1/h
	Construction cost [€/m²]	/	3 - 6	2 - 5

*Unit costs presented in the previous table represent the average level in Finland. In other countries they may differ significantly because of general cost level of country and location of building [4]

Satu Paiho studied net present values for different building and district level renovation packages for a 20-year period using different interest rates and annual energy price growth rates. The results suggest that renovation of a district may be more feasible than renovation of individual buildings. [5]

2. Transforming energy refurbishment of districts

2.1 Tools for district renovation process

2.1.1 District Energy Concept Advisor (D-ECA)

The District Energy Concept Adviser (District ECA, D-ECA) was developed in 2012/2013 within the German research initiative EnEff:Stadt and internationalised in the IEA EBC Annex 51. The tool enables the target audience (urban decision makers and planners of energy efficient districts) to assess the energy performance of a city quarter already in the first planning stages when not many detailed information is available. It works with archetype buildings that are combined to a city quarter, and that can be quickly adapted to the real situation. Various energy planning variants regarding the building quality and the energy supply system can be compared to the current situation in the city quarter.

The District ECA in the version prior to EU MODER is available for free as German and international version at http://www.district-eca.com [8]. After a registration the interested, user-to-be receives a link, from where he can download the tool for free.

D-ECA can perform:

- Performance rating: Comparison between the energy performance of an actual district with the average energy performance of similar districts in the same country.
- Case studies of energy efficient districts: Presentation of case studies gathered for different countries.
- Energy efficient strategies and technologies: Suitable strategies and technologies for the energy efficient renovation of districts including links to specific IEA Tasks and Annexes dealing with these technologies.

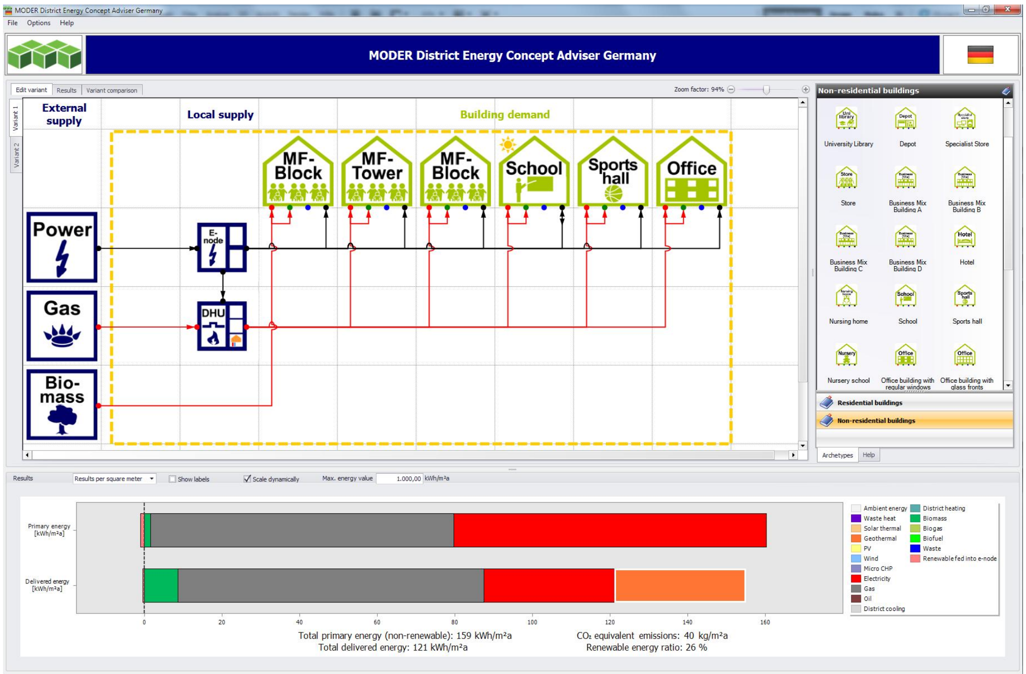

Figure 1: User-interface of the energy assessment of districts tool out of the D-ECA [7]

The calculation tool that allows the assessment of the energy performance of a district and various variations of alternative design or renovation is the core of the District Energy Concept Adviser. The calculation is based on the use of pre-defined archetype buildings. The geometry and user profile of the archetype buildings specific for individual country is fixed, while the energy quality of the building envelope and the included building services systems technologies can be chosen by the user. The user choses the suitable archetype buildings from the archetype library on the top right and inserts them into the assessment field on the top centre. By opening (clicking on) the archetype building icons, they can be further adapted to the real situation or the planning in the building parameter configuration window. Here the user can also find detailed information regarding the archetype building (geometry, user profile, etc.) in a pdf-document. The idea is that not each building in the district is a specific building in the calculation, but that similar buildings in terms of building type and use, building envelope quality and included building services systems are grouped to one archetype building with the total floor area of all buildings that are part of this group. Therefore districts with 30-40 buildings can result into much less archetype buildings in the District ECA (for example 5 used archetypes in the example Stuttgart Burgholzhof, where all buildings have been built at the same time (~ year 2000) as low energy buildings connected to a solar supported local district heating network or 11 used archetypes in the example Karlsruhe-Rintheim where buildings built in the 1950ies/1960ies, that have party already been renovated, have been assessed before and after the renovation and connection to the city's district heating network). However the tool manages also numerous archetype buildings within a district as we could see from a file that was sent to use by a user. It included about 150 buildings and the calculation worked without problems. The underlying calculation core is the German standard DIN V 18599 which is fully compatible with the CEN EPBD standards. The very detailed calculation has been simplified for the user with many pre-configurations, according to the most used system configurations. The user only has to decide for example what kind of heating system (based on the heating generation system) is included in a building and whether there is a mechanical ventilation system (with/without heat recovery) in use. An additional support for the user is that the building envelope can be pre-configured based on the building age. National databases allow this kind of pre-configuration. There are several building age period offered per country which then relate to typical building qualities or for later periods to maximum U-values required in the building regulation. The user can however also overwrite these pre-configured building envelope qualities per building component if he knows details or in case a renovation has already been realised. The architecture of the software is presented in figure 2.

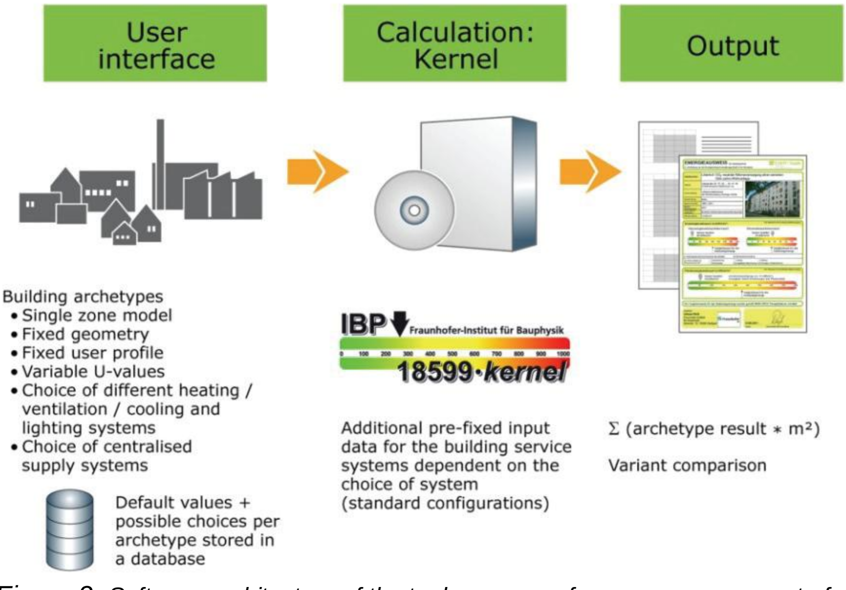

Figure 2: Software architecture of the tool energy performance assessment of districts as part [9]

2.1.2 City information model, visualization

Prior to construction or renovation of a district or even building for that matter, lots of information is needed in order to prepare useful plans for the project. We need information about the buildings in the district such as: year and type of construction, square footage of facades, windows and useful area, number of apartments, heating/cooling and electricity usage, water usage, information about the mechanical installations and user profiles. Energy models of buildings are still manageable, but district energy models quickly become very complex (many different types of buildings, systems, interactions, etc.). Currently the models are built manually, which is very tedious and time-consuming process, especially because of not user-friendly tools. This often leads to many problems with buildings alone, jet alone district. Therefore, different approach for gathering information, simulation and visualization is needed. We are working on creating a tool that would help with all that.

City Information Model (CIM) is rather new approach for a tool in district development. CIM is a 3D model of a city or district, and also contains information about buildings (location, orientation, address, year built, building type and information on areas, structures etc.). Various other information on buildings and districts that go beyond typical use of building and district models such as flooding possibility simulation can be added. That is why CIM models are a useful part of district level refurbishment design process. If there are no CIM model available, designers can generate one for the project area. It is a good platform not only for designers, but also for communication and information sharing. Collecting required data for large project area is a time-consuming task. CIM can help also with data collection. Since CIM is accessible through internet browser, it allows also several people input required data into right place directly. CIM can be connected directly to required databases where CIM automatically collects up to date data for each objects (usually buildings). All information updated into database also updates CIM automatically.

In order to manage some of the data from CIM we are using software called Apros. It is a design tool developed by VTT originally to simulate power plant processes. Since creation, it has received a lot of updates and improvements and can now handle building energy simulations, details of energy grids, pipelines and equipment in hourly time steps. Further development of Apros aims at utilisation of data format type from city information models – CityGML. It is a standardised data exchange format, which enables the modeling, saving, transferring and updating of the spatial city data. CityGML will speed up the district level energy refurbishment simulation by easing the initial build-up phase of the simulation model. This means

Apros energy simulation software can utilise 3D models, semantic and geospatial data of CIM. There are several ways in creating CIM. Project area, size, goals, and access to required data and databases are relevant issues to consider before start of the work. We propose work flow described in Figure 3.

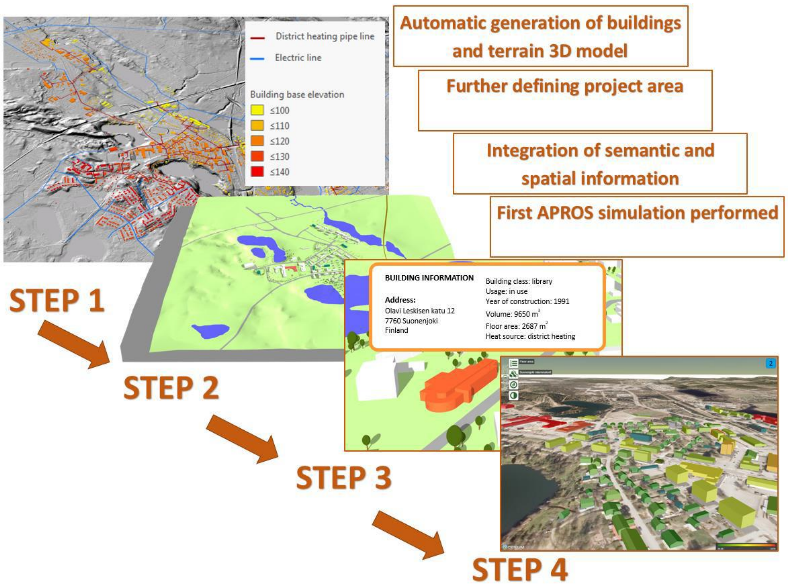

Figure 3: Suonenjoki CIM creation and Apros simulation process [7]

Proposed 4 steeps of the process:

1. Simplified generation of 3D models of buildings and terrain. Semantic information is not integrated in the model at this phase. There are several different options for creation of #d buildings and district (with different accuracies). We used LIDAR scanning point cloud data for generation of 3D buildings and terrain.
2. Identifying project area carried out together with city and local power plant personnel.
3. Buildng data collection and integration of the collected information to CIM as a semantic information for each building: (Building type, address, volume, floor area, year built, heat source, number of apartments, number of residents).

4. Exportation of CIM to CityGML for simulations in Apros and, visualization of results.

Visualisation tool is based on city information models that enables Apros simulation tool visualization in web browser. Different types of results and information about the buildings, planned renovation, and energy usage will be available through web browser. Figure 4 shows a test version of visualisation of Apros simulations utilising Case Suonenjoki city information model. This is a great advantage in the planning fase of the projects, because 3D Visualisation is a good tool to get the common understanding of the complex design challenges. It's easy to understand and comment 3D by the human nature – we all have eyes and we are used to handle spatial data.

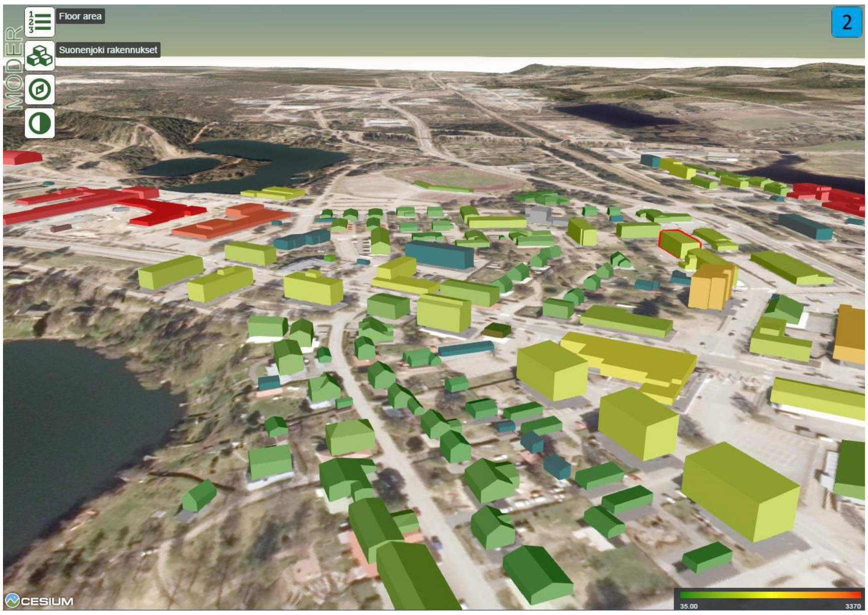

Figure 4: Test version of Apros simulation visualisation based on case Suonenjoki city information model. The colour code refers to improvements in energy performance of individual buildings [7]

3. Business models and tools for decision making

Several actors need to be involved in decision making on energy choices in refurbishment projects at district or neighbourhood level. It is also important to understand their preferences, needs, and goals. Therefore, we have to prepare several business plans for various stakeholders. We identified five key stakeholders:

- Local authorities,
- Building owners (private and commercial),
- Local Businesses,
- District residents, users,
- Finance investors.

Interest, willingness and collaboration of these stakeholders to renovate and achieve certain renovation goals at district level is a necessity. It is important to collaborate as early as possible, because district refurbishment projects require specific knowledge from different fields of science. That is why engineering companies and consultants need to prepare business models to activate and enable energy effective refurbishment at district level. When preparing business models for key stakeholders we need to take into the consideration vast amount of aspect (from financial aspects, benefits, needs, connections between stakeholders, etc.) that are country, region, district and project specific.

Each stakeholder group has different goals, motivation and challenges. Amongst listed groups we recognized local authorities, building owners and financial investors as groups of stakeholders that we should address first. When addressing local authorities we have to have a clear vision, communication strategies for tackling different interests, create a roadmap to reach targets and providing means and possibilities for investments. From building owners (private and commercial) point of view we have to focus on providing financial funds (subsides, loans, private public partnerships, etc.), managing services and strategies, providing good conditions and services for the users. When developing business models for local businesses we have to concentrate on developing sustainable energy and cost efficient solutions for development and refurbishment of districts (transport solutions, industry, construction sector, housing and retail). Local businesses should focus on efficient and sustainable energy usage, generation and distribution, reduction of emissions, development of building information smart services and also offer this solutions at minimum costs. Finance investors need to develop transparent, attractive, low risk funding options for various different scenarios. There are many different funding options for financing renovation of districts (loans, crowdfunding, EU funds, hedge funds, green bonds, private public partnerships, etc.). It is crucial to have good communication with building owners (private, commercial or public) and in a long run achieve profitability of investments in the refurbishment of districts. It is advisable that we should be using LCC approach in district refurbishment projects. All groups of stakeholders should be focusing on refurbishment of districts and thus provide affordable, energy efficient, consistent and pleasant living conditions for district users and residents.

3.1 Example of business model concept for energy refurbishment of district

3.1.1 Local authority point of view

When creating a business model for a local authority we have to be familiar with the challenges that we are facing:

- Organization
- Financial
- Communication
- Balancing interest of different stakeholder groups
- Building up trust and motivation for a renovation process
- Choosing optimal renovation scenario

In order to renovate a certain districts we have to overcome and address these challenges. We have to offer solutions and services that best fit and meet those demands. For example we can prepare: workshops for presentation and motivation of owners, residents, and local businesses. We can prepare district strategies with the help of EU projects, competitions, or student activities. Added value of well prepared business models can help authorities achieve higher success rate and trust level for execution of district renovation projects, higher quality of renovation, get public involved in the process, more affordable options, and overall better results.

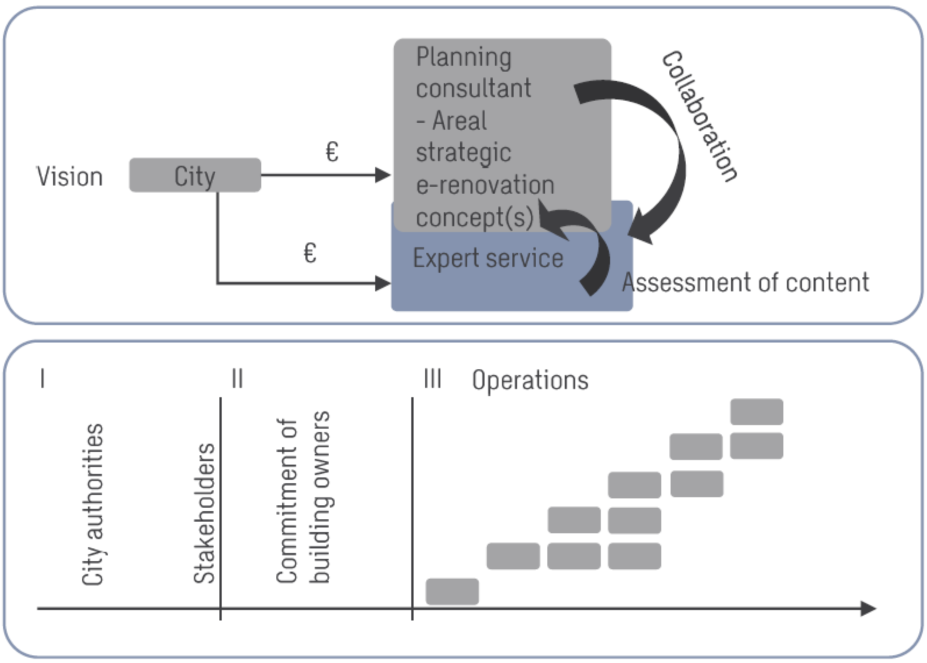

Figure 5: Illustration of some of the interaction in the process of district energy refurbishment [11]

4. Conclusion

More than 40% of energy is used in building sector, therefore, minimizing energy usage, utilization of RES and rational use of energy in buildings is a high priority. In order to optimize energy usage we have to build energy efficient buildings and mostly refurbish and optimize existing buildings. Until now majority of buildings is being renovated individually. Project MODER is developing tools for simulation (D-ECA) and visualization (Apros extension), that will help in the planning phase of the district refurbishment processes. We are also developing business models and solutions for various stakeholders in the district refurbishment process, with the hope of promoting and boosting renovation on a bigger scale.

District refurbishment offers a new approach to energy refurbishment of buildings. Compared to individual building renovations, district refurbishment offers several advantages (higher energy savings due to the bigger size of the project, higher energy efficiency, possibility of optimization of grids, lower costs of tendering process, planning and construction, shorter total refurbishment process, rise of property value due to nicer surroundings, etc.). A good example of financial saving is cost per unit. Usually higher the quantity - district refurbishment instead of individual building renovation, the lower the cost per unit (facade square footage, number of windows on the project).

Renovation on a district level also offers new business possibilities that arise from bigger scale of the project and optimization of NZEB. Companies can work on providing products, technologies and services for production of systems for renewable energy generation and storage, monitoring, automatization and optimization of processes, synchronization of consumption and generation, load matching, grid interactions and prefabrication. This could be very useful in districts with similar existing buildings.

District refurbishment is an interesting approach in renovation that should be taken into consideration. It presents a lot of challenges - that we are trying to solve, but also offers a lot of possibilities and opportunities for developing better buildings, districts, cities and future.

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