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The Smart City Block: another level of intervention

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Increasing the rate of renovation for the existing building stock is a crucial challenge for EU's energy policy. The Smart City Block (SCB) project proposes an innovative answer to this challenge. The underlying hypothesis is that introducing a collective dimension to renovation could result in increasing rates of renovation while also impacting positively the efficiency of the renovation and the social ties within urban areas. The collective dimension considered is the city block in Brussels.
The first part of this paper describes the theoretical part of the project that was necessary to develop an adapted methodology. It describes the SCB offering, Brussels segmentation and some results of surveys.
The SCB offering shows that many different options can be proposed to the city block dwellers, ranging from a collective insulation, efficient heating systems and shared photovoltaics to collective kitchen garden in the inner space of the block, shared vehicles or shared spaces. This is especially relevant for Brussels where city blocks often have an inner space that could be used. Besides, the segmentation of Brussels based on city block characteristics offers a typology that can be further used to target specific environmental or social deficit.
However, the collective dimension introduced in the project is challenging for western individualistic minds. In order to evaluate the acceptance of households, a survey was conducted on 4 city blocks in Brussels, representing over 450 households. It shows a clear willingness to investigate the concept further but only if concrete proposals with estimations of energy and financial savings are provided. Sharing space, equipment and activities was more positively accepted than what we initially expected. Although the attitude-behaviour gap must not be underestimated, this opening can be viewed as an evolution of lifestyles in some segments of the population. Governance and institutional arrangements are expected to play a critical role in supporting this evolution.
The second part of the paper relates to the practical part of the research.
Our selection process aimed at locating two types of city blocks: a "fuel poor" city block - where the inhabitants face comfort and energy cost difficulties – and a so-called "early adopter" city block – where inhabitants have a positive attitude for the SCB concept.

In the "early adopter" city block, located in Uccle, brainstorming meetings and coelaboration meetings were held as to elaborate an SCB model, with the inhabitants and in accordance with their aspirations and needs. Different solutions, including district heating, shared photovoltaics, shared vehicles and collective insulation were modelled both technically and economically. Financing solutions were also proposed.
In the "fuel poor" city block, located in Saint-Josse, we conducted a survey on the needs of inhabitants, commercial activities and owners (occupants or landlords). The need for increased energy efficiency is clearly expressed but we also identified the important barriers related to the ownership structure of the block.
Prior to the conclusions and proposal for further research on this topic, a section is dedicated to a discussion on the methodology and the hypotheses used during this research.

Keywords: Retrofit, co-housing, urban planning, energy efficiency, households, collective action, shared resources, mobility

JEL Classifications: R20, Q01, Q56.

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Abstract

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The SCB offering shows that many different options can be proposed to the city block dwellers, ranging from a collective insulation, efficient heating systems and shared photovoltaics to collective kitchen garden in the inner space of the block, shared vehicles or shared spaces. This is especially relevant for Brussels where city blocks often have an inner space that could be used. Besides, the segmentation of Brussels based on city block characteristics offers a typology that can be further used to target specific environmental or social deficit.

However, the collective dimension introduced in the project is challenging for western individualistic minds. In order to evaluate the acceptance of households, a survey was conducted on 4 city blocks in Brussels, representing over 450 households. It shows a clear willingness to investigate the concept further but only if concrete proposals with estimations of energy and financial savings are provided. Sharing space, equipment and activities was more positively accepted than what we initially expected. Although the attitude-behaviour gap must not be underestimated, this opening can be viewed as an evolution of lifestyles in some segments of the population. Governance and institutional arrangements are expected to play a critical role in supporting this evolution.

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Our selection process aimed at locating two types of city blocks: a "fuel poor" city block - where the inhabitants face comfort and energy cost difficulties – and a so-called "early adopter" city block – where inhabitants have a positive attitude for the SCB concept.

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vehicles and collective insulation were modelled both technically and economically. Financing solutions were also proposed.

In the "fuel poor" city block, located in Saint-Josse, we conducted a survey on the needs of inhabitants, commercial activities and owners (occupants or landlords). The need for increased energy efficiency is clearly expressed but we also identified the important barriers related to the ownership structure of the block.

Prior to the conclusions and proposal for further research on this topic, a section is dedicated to a discussion on the methodology and the hypotheses used during this research.

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This paper is a general and public summary of the research carried out between 2012 and 2016. Full reports remain the proprietary of Engie-Electrabel. Request to access these reports should be addressed to gilbert.vanpoecke@engie.com.

1. The energy context in Brussels

Since a few decades, climate change, scarcity of energy resources, cost of energy are becoming increasingly important in the political agendas. The envisaged solutions to reduce energy demand are mainly based on three pillars: the promotion of renewable energy[1], the promotion of energy efficiency[2] and finally promoting energy savings by behaviour changes[3].

As the two first pillars are essentially technical they have seamlessly been integrated in coherent policies. Within the scope of households and SMEs we are interested in, the Energy Performance of Building Directive (2010/31/EU) covers the objective of efficiency for new buildings or "major renovation". However, as stated in Directive 2012/27 (point 17), « The rate of building renovation needs to be increased, as the existing building stock represents the single biggest potential sector for energy savings. Moreover, buildings are crucial to achieving the Union objective of reducing greenhouse gas emissions by 80-95 % by 2050 compared to 1990. ». Increasing the rate of renovation for the existing building stock is thus a crucial challenge for EU's energy policy.

The behavioural change pillar is treated quite separately and in a manner that is dependent on the underlying theoretical behavioural frameworks. With theories such as the planned behaviour (Ajzen, 1991), behaviour changes should be triggered through increased information on energy consumption and/or grants to reduce investment barriers, while the social practices theory (Reckwitz, 2002; Shove & Walker, 2010) will essentially focus on collective symbols or energy challenges to induce change. A kind of dichotomy can be observed between rational or individual-based theories and the social or group-based theories. The debate is however not only theoretical. Indeed the former aims at inducing change at the micro-level (i.e. households or SMEs) whilst the latter addresses the macro-level (large groups such as towns, industry or the society in its whole).

Renovation is a major issue in many European cities where the building stock is old and badly insulated. The energy saving potential related to the built environment is huge and interventions to promote renovation for energy savings in different countries are numerous. In Belgium, for individual housing, the interventions used are generally limited to grants or subsidies. However, renovation rate in Brussels remains very low (beneath 2%) and insufficient to meet 2050 targets.

A key question that has not received attention it deserves can be stated as follows: would renovation be more efficiently promoted through collective initiatives rather than through individuals (households and/or SMEs)? And if so, at what level would have those collective processes the greatest chance of bringing results in terms of energy efficiency and social ties?

[1] Such as the climate and energy package (Directives 2009/28/CE to 2009/31/CE)

[2] Such as Directives 2012/27/EU on energy efficiency or 2010/30/CE on labelling of energy-related products

[3] Such as the Intelligent Europe II program

2. Smart City Block, a 5 year interdisciplinary research project

The Smart City Block (SCB) project was developed to test an **innovative answer** to this challenge. The core hypothesis underlying this project is that, by introducing a collective dimension, renovation can be more energy efficient and less expensive. It could thus indirectly result in increasing the renovation rate.

The **collective dimension considered in the project is the city block**, defined as a small area of the city that is surrounded by streets or other public domain limits (railways, rivers, etc.) and that is mainly occupied by inhabitants. Most city blocks offer an inner space (gardens, buildings, etc.) that is edged by buildings on the street side.

Thinking in terms of renovation at the city block level opens thus **new opportunities for energy** efficiency, sharing and exchanging between people living in the city block. Many different options can be proposed to the city block dwellers, ranging from a collective insulation, efficient heating systems and shared photovoltaics to collective kitchen garden in the inner space of the block, shared vehicles or shared spaces.

The project does not limit itself to energy efficiency aspects or cost reduction but also evaluates the impact on **social ties**, such as sharing some appliances or growing a common kitchen garden.

The SCB project is thus introducing a collective dimension at the level of the city block for energy efficiency and for social ties. Undoubtedly, this collective dimension is challenging for western individualistic minds. It is also challenging at many other levels, such as the legal level for instance, with the issue of creating commons in what was previously privately owned. It is even challenging in terms of policy-making, as it introduces an intermediate level between the micro (individual) level and the macro level like urban planning. However, by grounding the reflexion on energy efficiency at the level of the city block, innovative solutions arise. This renewed vision of the city could play an important part in the crucial challenge of renovating the existing building stock as well as offering remedies to urban solitude.

There are of course pros and cons for renovating at a city block level rather than remaining at the more usual household level. Major aspects are summarised in the following table:

Disciplinary viewpoint	+/-	Smart City Block
Social acceptability	?	Acceptability of the SCB concept is highly dependent on the population and the built environment. Citizen-friendliness may be increased by sharing some infrastructures (garden, space, equipment, etc.) and developing new activities. Conflicts could also arise.
Economic	+	Scale effect can lead to cost reduction. Sharing infrastructures and costs can lead to operational costs reduction.
Environment	+	Possible increased building performance by having access to technologies only efficient at a certain scale (e.g. district heating) and as consequence energy and GHG emission reduction. Space efficiency can be increased by sharing some infrastructures (garden, space, equipment, etc.)
Legal aspects	-	The legal constraint to implement an SCB related to responsibilities, insurances, contracts between inhabitants may become complex.

Organisational aspects	-	The decision process as the SCB level requires more interactions between households. The management of common space/equipment requires effective governance and institutions.

Table 1: Pros and con for renovating at a city block level

As can be seen from the above table, the SCB concept is no silver bullet, but some of the advantages can be sufficient to overcome the disadvantages, at least within some groups of the population.

To asses these different points more in depth, the SCB research was initiated in 2012 by the Free University of Brussels[4], facilitated by the fact that all the necessary disciplines are available within the university, and sponsored by the main energy supplier of Belgium[5]. The competences that were necessary include engineers, architects, city planners, geographers, sociologists, psychologists, economists, lawyers, etc. This five-year project is managed by an interdisciplinary coordination team.

The choice of Brussels to carry out the research was rather obvious, given the geographical implantation of the university.

The first part of this paper covers some theoretical aspects that were the main focus of the first two years (2012-2013). Section 3 describes the SCB proposal offering while section 4 describes how the segmentation of the city at the block level was achieved. Some insights about the social acceptability of such a project are given in section 5 as a result of surveys.

The second part of the paper describes some key elements from moving from the idea to field experimentation that spanned over 2014 to 2016. The overall methodology is sketched in section 7, while the details of the selection process are given in section 8. The study of a specific city block in Saint-Josse is described in section 9. In a city block located in Uccle, multiple meetings were organised with the inhabitants (section 10) during which specific models and solutions were developed. Some of the most significant results are described in section 11.

Finally, section 12 is dedicated to discussion on the methodology and covers many points of possible improvements before the conclusions and proposals for further research to be found in section 13.

[4] Université libre de Bruxelles, Polytechnique School of Brussels, BEAMS.

[5] Electrabel / GDF-Suez

PART I: A THEORETICAL APPROACH

3. Smart City Block Offering

The diversity of the 5000 city blocks of Brussels is such that it is impossible to build a systematic list of actions that can be applied in all cases in order to save energy. However, a reasonable list of so-called "elements" can be sufficiently representative of various types of renovation patterns. An "element" is defined as any physical element – building, indoor or outdoor space, infrastructure, equipment or resource – that can be included within a renovation project to increase energy efficiency, environment friendliness, social ties or economic advantages.

We grouped the elements in three major categories:

- Environmental, covering aspects such as mobility, waste management, water and space within the block,
- Technical, including the envelope of the building and the technical equipment (heating, ventilation, air conditioning, renewable energy, electricity management services, etc.)
- Services and common equipment, mainly providing common spaces and equipment to enhance quality of life and promote social ties within the city block.

A typical example of environmental element is a shared garden within the city block. Besides creating a convivial space, depending on the population, an inner garden can also provide additional feeling of security, favour social ties and eventually help saving on the food budget. Technical elements are generally less dependent on the population sensitivity but need to yield energy or financial savings to be accepted. An example of such an element is a combined heat and power (CHP) with district heating (DH) for a number of dwellings of the city block. Finally, as examples for service and common equipment, we can consider a shared laundry or a shared electric vehicle. For a shared laundry, for instance, more robust and energy efficient appliances can be selected, households are freed from the space and the troubles of possessing their own individual appliance. City block dwellers can experience a subjective loss of comfort and availability and/or satisfaction of the recovered space and of increasing the relations with neighbours.

Each element is described using a template structured around seven sections: The "flow" section describes the technical flows to which an element is related. For instance, a heat pump produces heat and consumes electricity. The "space" section aims at enumerating the various constraints or properties of the space that is required for an element. For example, some elements require natural light or outside access, while other are better located in the basements. Similarly, the "equipment" section gives an overview of what is physically necessary to operate the element. It can include furniture, computers, washing machines, home cinema, etc. The two next sections "tasks" and "activities" relate to the humans actions required to make it work. The former enumerates the maintenance activities, while the latter gives a list of activities that can be grafted on the element, such as various social activities (e.g. courses, repair café, parties, etc.). Although this list cannot be exhaustive, it is of the utmost importance as many of the enumerated items can be strong incentives for an SCB. Next, an "advantage" section gives indication of the type of benefits (environmental, economical, functional, social or related to energy) that can be provided by the element. A "scenario" section gives some indications of the elements that best work together either for effectiveness of the solution or for increasing quality of life within the SCB.

The templates were filled in by specialists of the different disciplines. Over 50 elements were fully described and consolidated into a database for further processing. The advantages of creating a database are threefold: 1) it allows displaying the gathered information in various formats (paper,

electronic) and with various levels of detail, 2) it enables online dynamic questionnaires where the sequence of choices can serve as indicator of preferences, 3) it allows filtering of elements based on various criteria (such as available space) or on preferred activities or competences available in the city block.

The third step of the elaboration of the catalogue consisted in identifying the barriers to the SCB concept. They are very diverse by nature: economic, city planning, architectural, technical, legal but also social and psychological.

The fourth and final step consisted in an analysis of the relations between the elements. In many cases, elements can be linked together in scenarios, because they make sense together, either for techno-economic or for social reasons. Combinations of elements are called scenarios and can be either "technical" - if they are linked by a physical flow (e.g. electricity, gas, heat, water, etc.) - or "human" - if they are linked by social practices or if they bring new meanings or new modes of living together.

The creation of scenarios was eased by the existence of the database which allows automatic generation of "technical scenarios" based on the technical flows and the extraction of the "human scenarios". The relations between the elements are represented by the organic diagrams (Figure 1 and Figure 2).

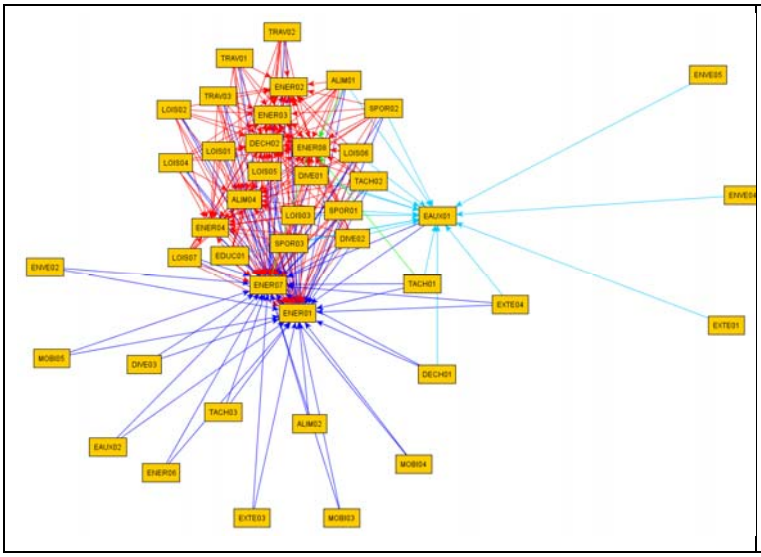

Figure 1: Organic diagram of technical relations between elements

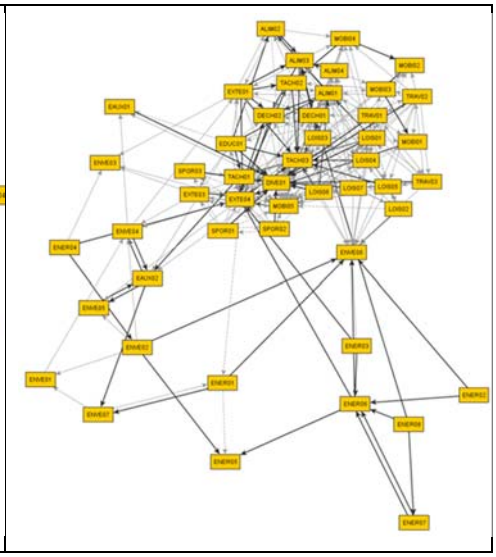

Figure 2: Organic diagram of human dependencies between elements

The distance between elements in these diagrams is inversely proportional to the number of existing links of a specific element. The colour of the links in Figure 1 represents heat (red), electricity (blue) and water (light blue) flows. The centrality analysis carried out on these diagrams showed the strong interest to focus of photovoltaic panels and cogeneration with small heat networks as a starting point for the technical aspects.

The same has been done for the "human scenario" (Figure 2). Centrality is less apparent, but different scenario appear related to common space and infrastructure (guest room, shared office, multifunctional room) or to leisure (garden, vegetable garden).

4. City-block segmentation in Brussels

Defining the SCB offer was a first step for analysing the social acceptability of the SCB concept. However, before performing a survey, we needed to have a better view on the structure of the built environment and the population living in Brussels. This section describes how the segmentation of the city was carried out.

Like most large cities in Europe, Brussels is characterized by its heterogeneity in terms of population and infrastructure environment. As the SCB offering includes elements that are by nature related to the built environment and to the way people live, we needed to segment the city according to both aspects and therefore to identify variables related to the morphology of the city as well as to the population and the way they live.

A list of 98 variables was compiled by researchers from different disciplines (engineering, architecture, urban science, geography, economy, finance, sociology, psychology). These variables are related to 6 main topics: Energy, Urbanism, Mobility, Environmental impact, Social impact and Financial. Unfortunately, the data for these 98 variables was not always available at a city block level. Some data was available at the so-call statistical-sector level (in average corresponding to 7 city blocks) but sometimes, data was only available at the neighbourhood or municipality level, which required to map highly aggregated data onto city blocks. Other variables could be calculated for each city block (e.g. public transport duration to reach some places, distance to parks).

The result of this data collection and processing phase is a database of 37 variables for 3.600 city blocks of Brussels. This database was then used to build a topology of the city.

4.1. Building a segmentation of Brussels

To achieve a segmentation including all aspects covered by the 37 variables, we ran a Principal Component Analysis (PCA) which is a mathematical process using an orthogonal transformation to convert a set of observations of correlated variables into a new set of linearly uncorrelated variables called principal components. It resulted in having more than 63% of the overall variance of the source variables being explained by 6 principal components.

The first two principal components already explain 43% of the total variance. The first one is related to the concentric organisation of the city and reflects the city development and is strongly correlated with the socio-economic variables. The second one explains the "canal zone" which was the most industrialised part of the town in the beginning of the 20th century and is now a district mainly occupied a low-income population.

The final step of the segmentation was obtained using Ward hierarchical clustering technique on the principal components. The optimal number of segments was determined to be 14 when the loss of inter-segment variance remained acceptable. Each segment can therefore be considered as reasonably homogenous. The segmentation is given in Figure 3 on which the "canal zone" and the concentric structure of the city are clearly visible.

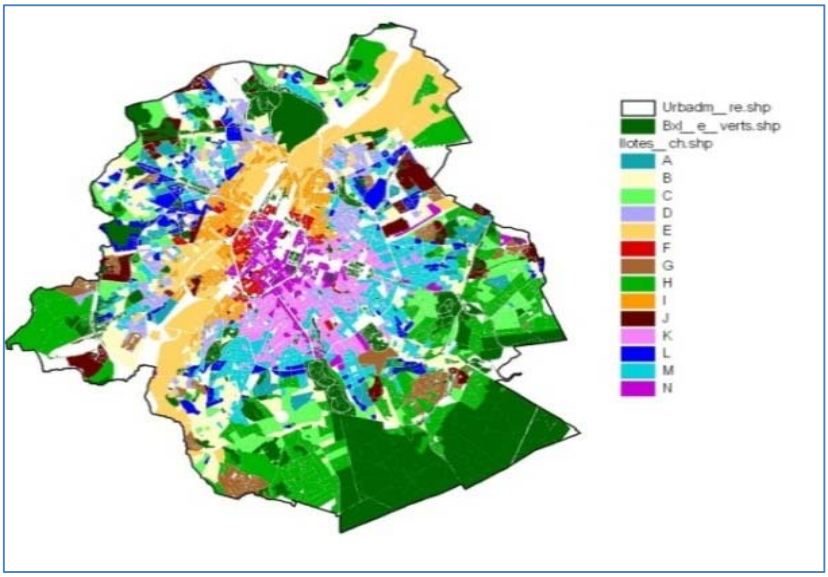

Figure 3: Topology of Brussels

4.2. Selecting city blocks to be surveyed

Each of the 14 topology groups having its own characteristics in terms of population and built environment, we needed to select a limited set of city blocks to carry out a surveys.

When searching for city blocks where energy savings could be important, we needed to locate area with a high 'environmental deficit'. A specific indicator was constructed to evaluate zones with high dwelling consumption (gas and electricity), low population concentration, low public transport availability, etc. Conversely when searching city blocks where SCB could bring an added value from the social point of view, we needed to locate area with a high 'social deficit'. Similarly a specific indicator was constructed for evaluating zones with excessive population concentration, badly insulated dwellings, low socio-economic indicators, etc.

The value of both indicators is plotted on Figure 4 for the 14 identified segments, the size of each circle being proportional to the number of city blocks of the segment. This graph was the basis for selecting three segments to carry out the survey:

- Segment H: highest environmental deficit and high socio-economic profile. Its 176 blocks are located in the older periphery (high net-worth individuals), with very strong presence of luxury detached or semi-detached houses and large gardens.
- Segment I: highest social deficit and low socio-economic profile, 396 blocks of old dense central districts, low socio-economic level, with domination of old joint buildings and remains of the industrial function.
- Segment M: an intermediate segment representing with the A, K and L segments approximately 50% of the city block of Brussels. With its 677 blocks, segment M is the largest segment, mainly composed of apartments in joint buildings, above average social status, part of the first dense crown, mid-20th.

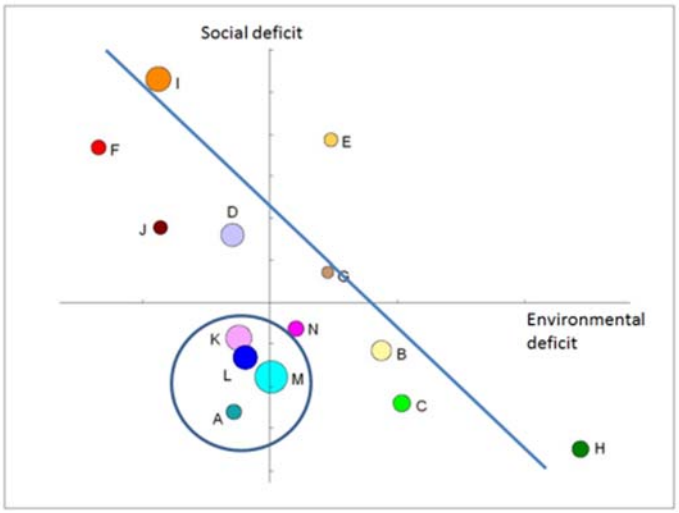

Figure 4: Environmental and social deficits

5. Survey methodology and results

The objective of the survey was to understand people's reactions to the SCB concepts, rather than to evaluate the intention to participate to such project. We therefore selected only one or two city blocks within each of the three segments. The survey included a quantitative questionnaire and interviews.

5.1. Methodology

The paper questionnaire that included 41 questions covering all themes relevant to an SCB project was distributed to all dwellings of the selected city blocks. The same questionnaire was also available on internet. Information sessions were also organised close to the surveyed blocks in the evenings.

As can be seen in Table 2, the percentage of answered questionnaires varied considerably from one block to another. In segments H and I, the very low participation to the survey was attributed to:

- the lack of financial motivation to participate to efforts in order to improve energy efficiency in segment H (while this is the group with the highest environmental deficit) combined with the above average age of the concerned population.
- the difficulty to communicate with the population in segment I was related to both a language and a cultural barrier. Difficult working conditions also played a role in the lack of interest of the population although the potential impact of renovation in such a city block is considerable.

Segment	Dwellings in selected city block	Paper answers	Internet answers	Coverage
H	92	3	4	8%
I	92	1	1	1%
M (1)	151	3	24	18%
M (2)	400	43	0	11%

Table 2: Answers to questionnaires

The survey coverage is better in segment M which can be explained by the higher socio-economic profile of the inhabitants. For this segment two blocks were selected: one was selected according to

the general selection methodology (M1) while a second one was specifically chosen as being part of a local committee active in the field of environment and energy savings aspects (M2). Although we expected the presence of the local committee to bring a positive bias on the number of answers to the questionnaire, this was not the case. However, the number of participants and their motivation to discuss during the local information sessions was significantly higher.

5.2. Main findings

Besides the lack of interest of inhabitants of segment H, the inappropriate methodology used to approach segments I, the surveys provided us with some interesting findings. Some of them are related to the organisation of the survey itself while others are related to the qualitative and quantitative questionnaires.

- **Need for local relay:** The organisation of the information meetings highlighted the need to first identify a local relay – a person or an association – to increase the number of participants.
- **A still too abstract project:** While the SCB concept was in general well accepted by the population in the M segment, the main issue stated during the meetings was the expectation of a concrete proposal on the specific city block from where the inhabitants came from.
- **Environment:** Most respondents provided answers to environmental-related questions. Noise, lack of green space and parking were the most reported problems of the inhabitants. Providing solutions to these problems was indicated to be a main driver to participate to an SCB project.
- **Usage of technologies:** Based on a list of proposed technical elements, the percentage of answers indicating that a household was ready to envisage specific technologies is globally 22% but with significant variations between the type of elements:
    - Technologies perceived as too complex or too innovative (district heating, cogeneration) seemed less attractive. This could be due to a lack of understanding within the population, showing the possible impact of education and communication.
    - These results may further be differentiated between renters (17%) and owners (83%) of houses, showing less positive answers for renters (13% versus 25%).
    - There was no correlation between the intention to renovate and the level of the energy bill (correl =-0.01).
- **Attractiveness of new shared spaces, equipment and activities:** Some activities related to inner spaces of the city block, such as a vegetable garden, composting, playground and workroom, have a high acceptance level. For instance regarding the vegetable garden, 41% were highly favourable and another 31% open to the suggestion. However, activities felt as more intimate, such as a shared kitchen, storage, office were rejected by a significant number of households (above 45%).

6. Other dimensions of the project

Other dimensions were also explored within the SCB project such as stakeholder analysis, financial and non-financial incentives as well as the governance.

Salient stakeholders identified in the private sector (e.g. architects, private developers, etc.) as well as in the public sector (local public authorities, regional authorities) were approached, using qualitative interviews.

The financial incentives provided by the public sector at the local and regional levels were listed and compared to the SCB offering to see how well they matched. However, the analysis of incentives

carried out in the SCB project goes beyond only financial incentives, as four types of incentives were considered (Table 3):

Type of incentive	External to the city block	Internal to the City block
Financial	Subsidies offered by public authorities	Financial gains due to economies of scale, sharing, production within the city block
Non-financial	Complementary currency systems developed by public authorities (e.g. Eco Iris)	New appliances, services, space, activities, less problems of mobility, etc. (e.g. new kitchen garden, common room, better washing machine, new parking spaces)

Table 3: Types of incentives

The non-financial incentives (NFI) cover two different realities according to whether they are external or internal to the city block.

As external NFI's, we considered complementary currency systems developed by public authorities. Complementary currency systems have in common to use another standardised unit than the euro to mediate exchanges (e.g. Air Miles, LETS systems, etc.). Although there is a great diversity of such systems that "are designed to operate in parallel with, as complements to, conventional national moneys"[6], we have focused on the emerging trend of using complementary currencies as policy instrument for sustainability[7]. In these systems, public authorities play a major role and use complementary currencies as a "non-financial" incentive to promote more sustainable behaviours.

As internal NFI's, we have considered the new opportunities that an SCB can offer. Planting a new kitchen garden, benefitting from a common room to organise parties or activities, solving parking problem by having access to the inner space of the city block, are all possible reasons to appreciate developing an SCB for one's city block.

The sharing and exchanging processes require discussions, decisions and organisation that are covered by the concept of governance, nicely described in the works such as 'healthy communities'[8] and 'grassroots movements'[9]. However, the development of some form of organisation between the residents is known as a major issue for cohousing communities (Kirby, 2003; Mulder et al., 2006; Sanguinetti, 2012; Williams, 2008). This is even more likely to be the case in retrofit communities, such as is proposed in the SCB model, where there is no self-selection of residents, contrary to what happens in most grassroots cohousing communities. These concerns relate to problems of collective actions where collective interests might be in conflict with personal interests (Olson, 1971; Dawes, 1980). Indeed, in retrofit communities such as proposed in SCB, it is vital that residents contribute, in one way or another to the sharing and exchanging processes, if only for avoiding deterioration of commonly shared items over time. Most interestingly, we could mobilise the work of Elinor Ostrom on institutional arrangements for collective actions[10] in order to explore this dimension of the project. Indeed, even if Ostrom's work is mostly focusing on natural resources, she, herself underlined that many of her findings could also be relevant in other context, including communal property regimes in housing development (Ostrom, 2000). Her work on common pooled resources where actors have important obligations towards the community were especially relevant for our case (e.g. Zanjera irrigation communities in the Philippines in Ostrom, 1990).

[6] Lietaer et al. (2010, p 99)

[7] Joachain and Klopfert, 2012

[8] Tom Wolff (2003)

[9] Gillian Kaye (2001)

[10] Elinor Ostrom, 1990

PART II: FROM THEORY TO FIELD EXPERIMENTATION

7. Objectives and methodology

The first part of this paper was about the theoretical phase of the SCB project, necessary to put the scene in place: the analysing of the structure of Brussels (segmentation in city blocks), the definition of the catalogue of available elements and the initial surveys. The second phase of the project which started at the end of 2014 focussed on defining and modelling real solutions for two city blocks.

The reason for selecting two existing city blocks is a consequence of the survey described in section 5. Indeed, the survey performed in 2013 showed important differences in the willingness and motivations of the inhabitants to participate to the elaboration of a detailed SCB project. We decided to select some city blocks where we can expect to elaborate, with the inhabitants, a personalised SCB project in accordance with their aspirations and needs.

As a result of multiple brainstorming sessions within the research team and other stakeholders, we decided to concentrate on two categories of city blocks in particular:

- The "early adopters" which are city block in which inhabitants are particularly interested and receptive to SCB ideas.
- The "fuel poor" (people in fuel poverty) for which it is necessary to use relays whether for reasons of language, culture, sensitivities, trust, etc.

Because of time and resource constraints, we selected one block for each category. The long selection process started with a call for proposals launched via a website and posters. Multiple mailings were sent to connect with local authorities, inhabitants and the non-profit world. Among the 11 submissions we received, two types of candidatures emerged from this process and can be grouped in "top-down" and "bottom up" initiatives depending on the initiator (local public authorities or the block inhabitants).

The final selection of the two city blocks was based on a series of technical and human criteria measuring all pertinent characteristics for the selection of the blocks. After finalising the selection process - detailed in section 8 - two city blocks were identified:

- A city block in Saint-Josse emerged from a top down candidature initiated by the mayor and is mainly made of inhabitants renting from social housing and confronted to fuel poverty (difficulty to pay their energy bills). It is a dense area of the city mixing inhabitants with small industries and restaurants.
- A city block in Uccle came from the inhabitants themselves and is therefore a typical bottom up candidature. It is a small block made of around 100 houses and with a rather large central area made of gardens and public areas. Inhabitants are characterised by a higher economical and educational level compared to the average in Brussels. When we met them we were able to qualify the inhabitants at the source of the candidature as "early adopters". The presence of a school and a church together with some green space available at the centre of the block were noted as potentially positive elements for example to envisage implementing local renewable energy production based on technologies such as cogeneration and heat network.

Different approaches were used for these two city blocks:

- At Saint-Josse, as communication was difficult with the inhabitants, we needed to work with the authorities and the local associations (section 9).
- A Uccle, we went through a complete coelaboration process (section 10)

8. The selection process

A critical phase of this project is the selection of city blocks. Indeed, the objective is to find at least one city block where the inhabitants are ready get involved in the project. How can we find such city blocks? How can we define the criteria that make it possible to select of one or more city blocks out of the 5000 blocks of Brussels?

Some relevant criteria are related to the built environment and can be evaluated from data gathered during the segmentation (section 4), while others are related to the motivation and interest of a sufficient number of stakeholders. In this research, we distinguish "bottom-up" and "top-down" projects depending on the stakeholder that initiates the project.

- Bottom-up is used to qualify a project that originates from the inhabitants themselves without an explicit intervention of the public authorities, even though they make use of existing frameworks such as the "quartier durable citoyen".
- Top-down is used to describe projects that originate from the public authorities themselves (municipalities or region), generally in accordance with city development planning or with concerns about fuel poverty. These projects can be linked to important financing interventions such as "contrats de quartiers". We also include in this groups, projects that are initiated by promoters as the starting point does not emerge from the inhabitants.

As we did not want to limit ourselves to only one group, we adopted a selection methodology initially open to all stakeholders. It is based on five steps:

- Definition of an "à priori" set of criteria that we subjectively consider as important for a possible collective renovation. These criteria focus of the built environment (size, age and type of building, etc.), on the existence of local associations and neighbourhoods (useful for a bottom-up approach) and on the support of different levels of public authorities.
- A "call for proposal" (CfP) was issued. To increase the chance of identifying groups of inhabitants that are susceptible to adhere, we took contact with municipalities and civil associations. More than 20 meetings were necessary to identify the 28 potential neighbourhoods and establish a dedicated mailing list of 354 persons. The CfP was published on a web site, promoted by many municipalities and by mailing. Leaflets were made available. The CfP resulted in 11 valid proposals for city blocks, covering 8 municipalities.
- Each of these city blocks was visited and meetings held with the representatives. Additional data was collected as to fill in a score card. The four most adequate candidates were selected based on weighting these different technical and human criteria, as can be seen in Figure 5:

	Auderghem1	Etterbeek2	SaintJosse1	Uccle1
Criteria à priori (validated from DB and meetings)				
Building characteristics	OK	OK	OK	OK
Bottom-up score	1	2	2	3
Top-down score	4	5	5	4
Score card afetr visits and meetings				
Building and space characteristics	3	3	2	2
Mobility and economic mixity	5	6	5	3
Population characteristics	4	5	4	5
Pulblic authority support	2	2	3	0
Total Score	**19**	**23**	**21**	**17**
Selection for short list	**Early Adopter**	**Early Adopter**	**Précarité**	**Early Adopter**

Figure 5: Short list selection of city blocks

- The next time-consuming step involved the representative of the city block. Each of them was asked to organise evening sessions with the inhabitants as to measure the level of interest for the project and identify relays to start the co-elaboration process. During these meetings, the SCB team presented the concepts and provided leaflets, posters and papers.
- The representatives were finally charged to distribute a short questionnaire of 4 questions to all inhabitants of the city block. It aimed at evaluating the willingness of inhabitants to participate to brainstorming meetings, to get implied in the coelaboration process and to accept interviews.

This final selection was based on the number of inhabitants that attended the meetings and on the number of responses to the questionnaire of the inhabitants.

Two city blocks were selected:

- A "bottom-up" block located in Uccle, for which 28 answers were received.

  Composed of 93 residential dwellings, almost entirely constructed before 1990, this block is quite typical for Brussels with its 54% of attached houses and 25% of apartments. Although there are no tertiary activities, there is a school in the centre of the block and a Church. Population is composed of roughly 20% of young people (less than 20 years old) and 20% of elderly (over 65).

  The proposal was introduced by a representative of the "Quartier Durable Oxy15".

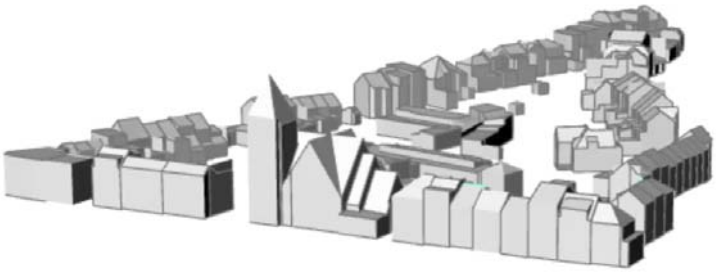

Figure 6: Model of the city block in Uccle

- A "top-down" block located in Saint-Josse.

  This city block, located on the "place Saint-Josse" in the center of the Municipality, is mainly composed of buildings of 4 to 7 stories with many commercial activities (shops and services). The vast majority has been constructed around 1900. Three social housing builidings provide 110 dwellings of which 46 are unoccupied because of renovation. The remaining 72 dwellings are either rented or occupied by the owner. The Municipality owns the inner space and many buildings, including the school ("La nouvelle école") and the sports hall located in the center of the block. The average age and the average income of the population are below the Brussels averages.

  The proposal was introduced by a representative of le "Contrat de Quartier Axe-Louvain" with the support of the Municipality.

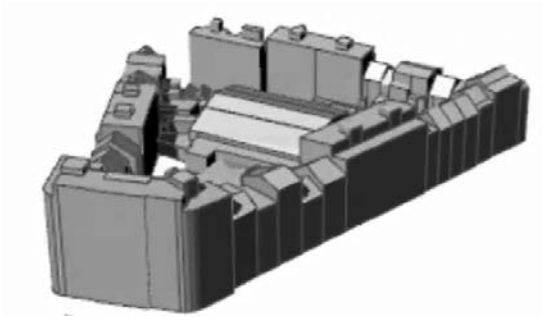

Figure 7: Model of the city block in Saint-Josse

The whole selection process was very time-consuming and kept us busy for more than one year. It allowed us to identify two blocks; one considered as an "early adapter" that we expected to be one of the most susceptible to go further in the adventure, and the second one, a "fuel-poor" having a municipality strongly implied.

However, our experience showed that this process could significantly be improved:

- From the communication point of view, more attention should be given to the simplification of the main message and its attractiveness. Indeed, as SCB concept is not easy to describe in

a few lines, visual tools and strong argumentations should be provided straight from the beginning, both for landlords and for tenants.

- We also noticed that the CfP should also have been communicated thought other channels than the ones we selected (mainly municipalities and local associations). Estate promoters and architects should be invited earlier in the process.
- Though the last step of our process (meetings with the inhabitants and questionnaires) does give a very good idea of the inhabitants that are willing to get involved, we missed part of the social complexity of the relation between them. We now strongly believe that it is worth to add an important number of in-depth interviews of inhabitants in the selection process as to be sure to catch the underlying dynamics of the social ties.

9. Fuel poverty

Although the target of the SCB concepts is to promote energy savings and social ties through collective renovation, it became clear, after the different interview carried out in the so-called "social deficit" areas with high (section 5, page 10), that collective renovation is also a means to increase the comfort and/or reduce financial stress related to energy consumption. In such areas, although many "elements" defined in section 3 are still valid, the aim of the renovation is more social than environmental.

The interviews showed us how difficult it is to communicate with fuel-poor tenants and for various reasons: language, cultural differences, short term vision for immigrants that plan to move as soon as possible, relationship with the landlords, financial means, knowledge, clandestinely, etc. These reasons pushed us to select such a city block (category I in City-block segmentation in Brussels) but where we could rely on an effective support from the Municipality and from local associations as to establish communication with the population.

The "Cudell" city block (shortly described in previous section) was perfectly suited for our purpose. Indeed, the answer to the RfP was introduced by representatives of the "Contrat de Quartier Axe-Louvain" with the full support of Mayor. We were asked to present the SCB project during a general assembly gathering many inhabitants. Moreover, two persons of the Municipality were available to help us with the interviews and for setting up contacts with the inhabitants. Besides the Municipality, we also got support from many associations: Fabrik Fabrik (Réseau Habitat), La Ruelle, Service de Rénovation Urbaine, Atrium nord, la Calame and some representatives of social housing.

The survey aimed at three distinct groups: tenants, commercial activities and owners (occupants or landlords). Interviews were done by going door to door, during local events, in laundry rooms and other places of the city block. For landlords, further information was collected through the cadastral administration. In total, 24 questionnaires were filled in.

Not surprisingly, the results (see Figure 8, below) show the importance of energy savings for all three targeted groups, followed by environmental considerations for the inhabitants and events requests for the commercial activities.

Concerning energy, the local Municipality has already made important efforts for providing information, support and subsidies to promote energy efficiency investments. However, the possibility of collective renovation in this city block is almost impossible for the following reasons:

- As the "Contrat de Quartier Durable Axe-Louvain" is already in place, technical and financial resources have already been allocated and there is no possible flexibility at this stage.
- The split of responsibilities between all the various stakeholders of this city block (Municipality, social housing organisations, school, sports hall, etc.), the separate plans and budgets does not allow a coordinated and integrated solution. This is a pity as this city block is a perfect candidate for solutions such as district heating.

- The school that occupies a large part of the central space of the block should move in the near future but no clear time frame.
- Most of the inhabitants of the social housing are reticent to express opinions that could go against the interest of a Municipality as they fear possible reprisal and some also fear that increasing the comfort standard could result in gentrification.

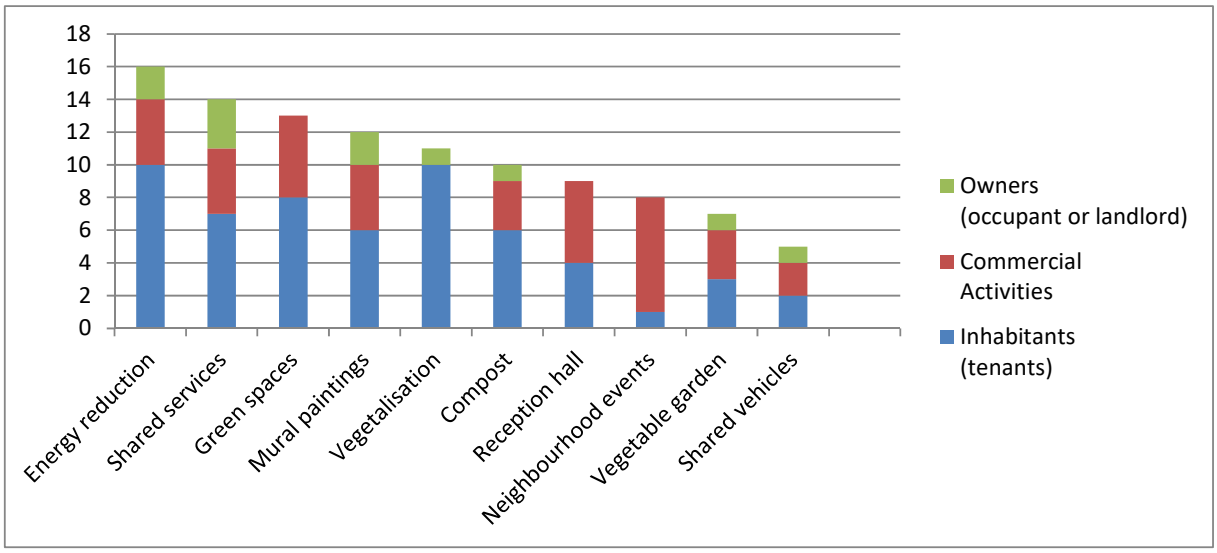

Figure 8: Preferences for collective renovation in Saint-Josse

To summarise our experience in this city block of Saint-Josse, we can say that the need and the benefits of collective renovation can be very important but cannot be achieved without a strong will and involvement of the Municipality to organise and invest. Communication with the inhabitants and the landlords is difficult and their investment capacity is very limited. Moreover, as renovation would lead primarily to increase of comfort rather than financial savings, the possibility to call on third party investors seems compromised.

The "Contrats de Quartier Durable" provide important financial means and resources for developing collective renovation. However, to make use of the, it is necessary to be involved during the initial definition phase. Once defined, the flexibility of such instruments in insufficient to initiate collective renovations processes such as used in the SCB project.

10. Needs and requirements of early adopters

Creating a common understanding of what is needed and/or desired in a city block is a difficult communication exercise. On one side, there is the SCB team with the set of available studies, a list of possible elements to implement, ideas and technical skills. On the other side there is a city block with its built environments, its history and, more importantly, a large number of individuals making up families with different roles (owner, tenant), means, skills and sensibilities.

To cope with this complexity, we collected two different streams of information between May 2015 and December 2015: first questionnaires and interviews and second, a number of meetings with the inhabitants.

As this process is very time consuming, it was only carried out in the city block of Uccle.

10.1. Detailed information gathering

All inhabitants were asked to fill in a short questionnaire giving us a first view on the range of interests and motivations. 28 questionnaires were filled in rapidly but for the remaining 52 we needed to go door to door. In addition, we performed 13 in depth interviews, two of which were

related to the school. Questions were focussed on the family composition, the housing (state, energy consumption and usage), mobility aspects, social ties and on the expectations of the outcome of the SCB project.

Our sample interviews cannot be considered as representative of the city block. It was composed workers and retired persons (respectively 6/11 and 4/11) with a majority holding a university degree (8/11). About half of the sample was living in the city block before 1990 and the second half had moved in since 2011, showing a typical old city block with young families coming in.

All interviewed families have at least one car, half of which use it on a regular base. Car sharing is not common, neither is the usage of Cambio or Zen Car. Most families complain on the traffic and the lack of cycling paths. The number of parking places is controversial, as some would like to see them increase while others would reduce their number. Most inhabitants like their environment and appreciate the community spirit. Some collective activities are organised (compost, rue aux jeux, espaces fleuris par les habitants, fêtes des voisins, etc.).

The main expectations of the families were related to energy savings, better mobility (less traffic and more cycling paths), increasing the quality of the environment, shared infrastructures (terraces, vegetable gardens, play grounds, gardening tools) and providing help for more social activities (exchange of goods and services, intergenerational activities).

The school representatives were highly interested in the energy savings and were not against the principle of sharing infrastructure though directly invoking administrative and legal constraints for doing so. The director of the school is clearly interested in promoting an "éco-citoyenneté" quite in-line with SCB concepts, but pointed out that she could only encourage the teachers themselves and could not force them to do so.

The main difficulties invoked about the project are related the existing tensions between some inhabitants, the status of the Church (will it be classified or destroyed) and the organisation of setting up shared infrastructures if all do not agree.

10.2. Brainstorming and co-elaboration meetings

Once the city block in Uccle was selected, we entered into an intensive co-working process with the inhabitants and all other possible stakeholders of the project (local authorities, Real estate developers, architects, construction companies, public transport companies, Brussels Ministry of Environment). We organised five evening meetings with the inhabitants, the representatives of the school and of the church. The two first were brainstorming's and were followed by three co-elaborations meetings. To help us animating the meetings, we involved ECORES, a company specialised in citizen civil organisations using open innovation and collective intelligence emergence techniques. Communication was done though mailing, leaflets distribution and posters in all local streets. The number of participants ranged from 10 to 20. 17 inhabitants were present at two meetings at least.

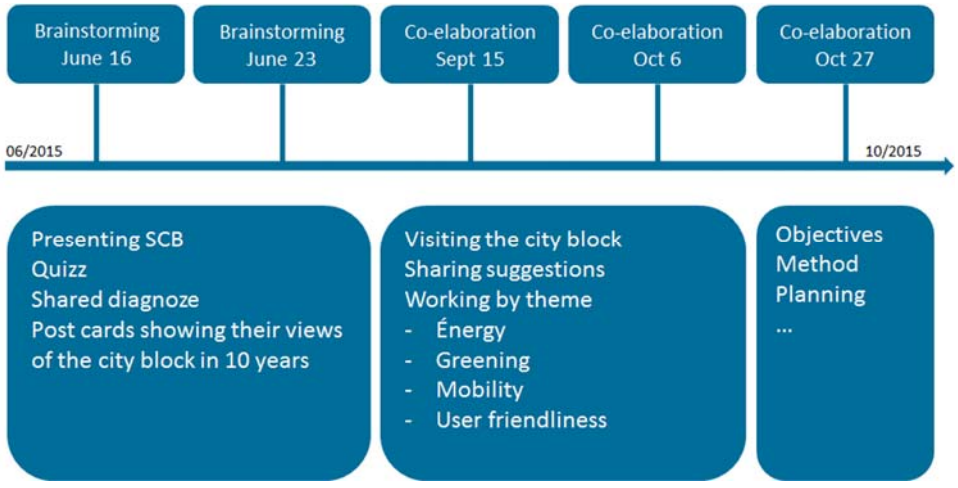

Figure 9: Brainstorming and co-elaboration meetings

The brainstorming meetings aimed at getting a maximum number of people on-board and to let them "dream" of an ideal city block. Short presentations, a quiz, games and thematic groups (energy, environment and shared infrastructures) were used to help getting the people communicate together and describe the positive and negative feelings about their city block. The two sessions showed that many persons were concerned about parking, noise, the future of the Church but, most interestingly, also on possible negative effects of the SCB project (democratic representation, people not willing to participate, creation of a ghetto mentality). However, the positive opportunity of the SCB project was clearly identified and many ideas were set forth (LETS, services exchanges, common infrastructures, promotion of photovoltaic, district heating and cogeneration, rainwater recovery, green roofs, shared electric vehicles, etc.).

Although inhabitants did not all agree on the present perception of the block, making them express their views of the city block over a period of 10 years surprisingly resulted in a relatively common vision of the future: low energy dwellings, local individual cars replaced by shared electric vehicles, mixed generations, elderly assistance, and many social and festive activities.

People's perception of the meetings was globally positive: "interesting", "promising", "thank you", "synergy", "motivation" and "cool" were the words used to express the feelings about the process.

Contrary to the brainstorming meetings where people were encouraged to dream a future, the aim of the three coelaboration meetings was to identify concrete sub-projects they would effectively like to see implemented if the city block on short term. A newsletter, summarizing the results of the brainstorming was distributed in the letterbox prior to these meetings.

The determination of the sub-projects starts by understanding both the wishes and the needs of the inhabitants, but also the development steps, the organisation and the individual involvement. The difficult part is to collect information equally from all participants and avoiding some persons constantly bringing forth their own interests.

Three working groups emerged. The mobility group worked on traffic nuisance and increasing cycling path. The energy group worked on possible scenario for increasing energy efficiency in the block, targeting the heating system of the school and the Church, the insulation of dwellings and introduction of more renewable energy A third group aimed environmental considerations such compost, greening houses and increasing the number of trees and flowers at different spots of the block.

During these sessions, all aspects of the project (technical, economical and legal) have been discussed in depth. At the end, the inhabitants were able to group their needs in 4 categories and to list the projects they would like to have realised in their city block:

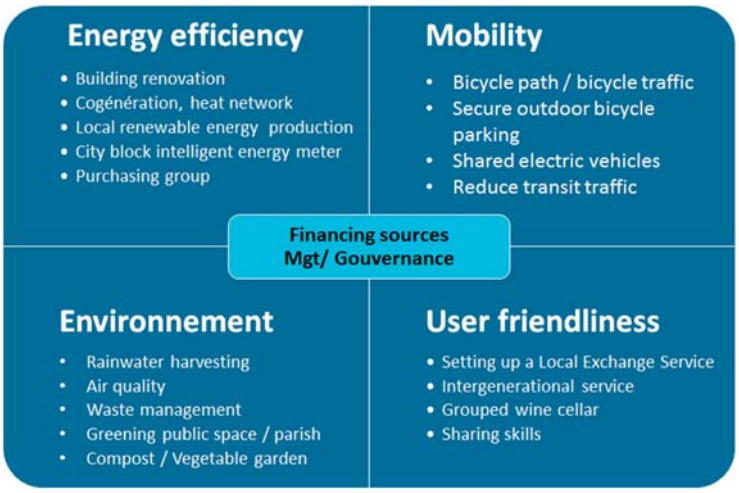

Figure 10: Research questions for the city block of Uccle

Financing and governance aspects came as two equally important transversal themes.

As all items could not be studies in detail taking into account available time and resource, the inhabitants and the SCB team agreed to focus on the following list of projects:

- Energy efficiency: Combined heat and power (CHP) and district heating (DH), collective insulation of houses, renewable energy production.
- Mobility: cycling path, shared electric vehicles.
- Environment: rain water recovery, air pollution, space greening, compost.
- Conviviality: promoting intergenerational services, sharing competences, organising bulk purchases.

Generally speaking the process allowed inhabitants to appropriate their city block and express their desires. The representativity of the inhabitants could have been better. Indeed, as can be seen on Figure 11, out of the 104 persons we had contacts with, 44 attended to at least one meeting, 19 attended to at least two meetings but only 8 attended to at least 4 meetings, showing that the core motivated group is quite small. Figure 11 also shows a drop in participants for the third meeting (due to conflicting agendas early September), but the overall participation remained more or less constant.

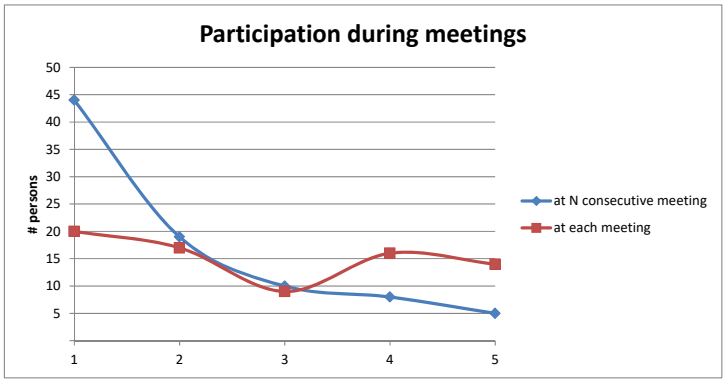

Figure 11: Participation during the meetings

Although the participants often expressed enthusiasm about the project, the overall impression is that of passivity – the inhabitants relying on the driving force of the SCB team –, maybe due to an insufficient number of young inhabitants in the workgroups.

However, the understanding of the technical, economical and organisational possibilities clearly increased from the first to the last meeting, showing the positive educational impact of such projects on inhabitants.

There was a minority of inhabitants that were more concerned by conviviality than technical or financial aspects of the project. They were wishing to promote social ties and intergenerational solutions. Unfortunately, these aspects were did not capture enough attention during the brainstorming meetings to create a working group in these topics, as if these non-material aspects strive to exist in practical and concrete projects.

During the organisation of the meetings, we regretted the lack presence of some stakeholders (Municipality, Church representatives) and of some inhabitants who could not attend in the evening though they expressed a desire to do so.

11. Developing solutions for Uccle

Based on the needs expressed during the meetings and summarised in Figure 10, our research team entered a full year of technical and economic modelling work in order to build concrete solutions

adapted to the specificities of the city block for most of the items. This part of the research was performed by last year master students and doctoral researchers in all the related fields, (energy engineers, architecture, economy and finance, lawyers, etc.). At the end of this elaboration process, all modelled solutions have been presented to inhabitants.

This section describes the main solutions that were studied for city block of Uccle.

11.1. District heating with combined heat and power

Over 90% of the dwellings are equipped with gas boilers for central heating and hot water generation. Combined heat and power (CHP) allows producing simultaneously heat and electricity with a better overall efficiency – estimated to 18% – and less emissions that producing heat with gas boilers and taking electricity from the grid[11]. However this technology is complex, it needs to be correctly dimensioned and requires a regular and professional maintenance. Because of these constraints, CHP is generally not applicable for small applications, such as individual households. However, under a number of hypotheses, CHP can be profitable for groups of dwellings and the profitability generally increases when there is a mix of usages. In our case, the presence of a school and a Church that both require heat at other moments than the households, offers an excellent opportunity. We only considered gas CHPs in our study.

Dimensioning a CHP is tricky because many factors need to be taken into account: the heat-need profile per hour, the electricity consumption while heat is produced, the nominal power of the CHP and the proportion of heat consumed by households and by the tertiary sector (i.e. school). These two last factors influence the number of green certificates that can be obtained during the life time of the system and thus the economical profitability.

Next to the CHP a district heating (DH) network must be developed to bring the heat into the dwellings. Ideally, the need for heat should be close to the CHP to avoid important losses in the pipes. To keep the heat-need density high enough, we studied the implementation of CHP and DH for 44 dwellings, the school and the Church. Heat needs were calculated using the actual energy consumption over 5 years with modelled heat-need profiles for the dwellings, school and Church. Electricity needs were modelled using Synthetic Load Profiles (SLP)[12].

The current energy needs are summarised by the following table:

	School (gas)	School (petrol)	Dwellings (6)	Dwellings (44)	Church
Natural Gas consumption (HHV) [kWh]	58112	54423	109078	997798	109595
Natural Gas Consumption (LHV) [kWh]	52301	50867	98170	898018	98636
Approximation boiler efficiency	85%	75%	85%	85%	80%
Heat Demand [kWh]	44455	38150	83445	763315	78908
Electricity [kWh]	21257	/	17096	192784	2964

[13]

Table 4: Energy consumption in the city block

We first dimensioned the CHP using the monotone-curve method which optimizes the energy consumption and the emissions, then using COGENSIM[14] software that optimizes the profitability aspects. The two methods yield different results as shown below:

[11] See for example IBGE (2009), GUIDE COGÉNÉRATION, Comment estimer la pertinence d'une installation de cogénération, 2009, http://www.environnement.brussels/sites/default/files/user_files/gids_2009_guidepertinencecogen.pdf and Energuide, Sibelga. « Qu'est ce que la cogénération ?». Site Web : http://www.energuide.be/fr/questions-reponses/quest-ce-que-la-cogeneration/615/http://www.energuide.be/fr/questions-reponses/quest-ce-que-la-cogeneration/615/.

[12] Synergrid, "Synthetic load profiles, slp." http://www.synergrid.be/index.cfm?PageID=16896&language_code=NED,2016. Accessed: 06/05/2016.

[13] MFE Devos

[14] ICEDD: Institut de Conseil et d'études et développe-ment durableYves Lebbe, "Cogensim 3.11: logiciel de simulation pour le calcul du dimen-sionnement et de la rentabilité d'une installation de cogénération," 2011.

	Monotone method	Cogensim method
Nominal electrical power	73 kWe	49 kWe
Nominal thermal power	122 kWth	86 kWth
NPV	101547 €/lifetime	167333 €/lifetime
Return on investment	4,80 y	2,92 y
Operation hours / year	4970,74 h/y	5720 h/y
Number start/stops	94	77
Electrical energy produced by the cogeneration unit	340393 kWh/y	266532 kWh/y
which is sold back to the grid	203873 kWh/y	113173 kWh/y
which is autoconsumed by the participants	136520 kWh/y	153358 kWh/y

Table 5: Comparison of Monotone-curve and COGENSIM methods

Next to the CHP, the complete system also requires two additional gas boilers of 91 kW and 311 kW respectively, 422 m of pipes for the DH, 18kW substations in the dwellings and 60 kW substations in the school and Church. The substations are dimensioned for heat and domestic hot water, allowing participants to recover space by removing their existing boilers.

The expected primary energy savings are of 190 MWh/year resulting in cutting down CO_2 emissions by 41 tons per year. The total investment, including the installations costs, is evaluated to 462 k€[15]. Different financing possibilities were explored. Crowdfunding and third-party investor (ESCO) showed to be the most adequate solutions.

However, promoting CHP and DH in existing city blocks meets a number of difficulties:

- Our study shows that the installation of CHP and DH in the Uccle city block is only profitable when assuming that the electricity produced can be shared between the dwellings (such as in a private networks). This assumption is however not fulfilled as today's Belgian legislation without specific derogations that are not easy to obtain.
- The profitability is computed of over a period of 10 years, including the complete amortisation of the DH installation. This means the profitability over the following years will be significantly higher.
- During the analysis, we confirmed the rule of the thumb, which specifies that DH is only profitable when the heat-need density is above 2.000 kWh/m/year. This minimum is reached in the city block we studied thanks to the presence of the school and some building blocks with apartments. Many city blocks in Brussels will not reach this minimum density.
- The willingness to effectively decide to go for the CHP/DH solutions is difficult to quantify, but seems closely related to the age of the existing boiler in the dwellings. 6 households and the school, for which the existing boilers need to be replaced, are definitely willing to go forward. The households that do not have an urgent need to change their existing heating system, even if they are interested in the solution, remain in a wait-and-see attitude. The impression of loss related to a stranded asset shows to be a strong demotivation factor.
- We also noted that, due to the subsidies rules, the price of the electricity reinjected in the grid and the green certificates allocation rules, the financial optimal does not match with the environmental optimal.

11.2. Photovoltaic panels

Photovoltaic panels (PV) are the main renewable energy source in a city such as Brussels and many houses and buildings are already equipped with PV. The decision on installing PV or not is generally based on profitability, which depend of the physicals aspects (orientation, shading and available surface) and financial aspects (green certificates and reinjection price of unused electricity into the grid). In the Brussels Capital Region, for PV installations below 5 kW compensation is

[15] MFE Mus

authorised[16], meaning that the price of the reinjected kWh is the same as the cost of a kWh, generally between 18 and 20 c€. However, this will change as from 2018[17] when the price of the reinjected kWh will be brought back approximately 4c€.

The end of the compensation mechanism both reduces the profitability of PV and strongly promotes auto-consumption of the produced electricity, the best profitability being achieved when all the electricity produced by the PV is consumed locally. This can be partially done with home automation (e.g. automatically starting machines such as dish-washer when the sun is shining) or by storage (in batteries or as hot water).

These different legal constraints discourage oversizing PV installations (for example for households having large available roofs areas and low electricity consumption) and therefore reduce the potential PV development in the part of the city where the proportion of single-family houses is high, like in the city block of Uccle. As for CHP and DH described in the previous section, we assumed electricity exchange between private households would become possible and evaluated the effect on auto-consumption and profitability of shared PV installations.

This study started by selecting all houses of the city block having a roof with correct orientation (from -55° to +45° from south), correct slope (between 15° to 45°) and without shading. The 18 houses were split into 4 groups, based on proximity. For each house, quotes for a PV installation were requested for each house, individually and globally.

The PV production (1/4 hour based) of each house was then modelled using the orientation of its roof and data provided by ELIA on the existing installed park of PV in Brussels[18]. The consumption of each house was evaluated using the electricity consumption during 5 years and the Synthetic Load Profiles[19]. From there, the auto-consumption rates and the power reinjected into the grid could be evaluated.

The results show that the grouping of the PV productions of houses increases the auto-consumption. Depending on the configuration and the size of the block, the increase ranges from 2.3% to 7.5%.

The profitability related to grouping has also been evaluated. The profitability increase comes from two factors: the cost reduction of the installation itself (scale effect) and the gain on the electricity bill related to the increased auto-consumption.

Investment costs are reduced between 1.4% and 4.5% depending on the size of the block. The net present value (NPV) and the internal interest rate (IRR) can be increased by 18.9% and 1.9% respectively. Payback time can be reduced from 12 years to 10 years.

These figures, although they should be recalculated with more precise data (actual load curves rather than SLPs), show the interest of grouping installation, production and consumption. However, as previously described, these figures rely on the possibility of exchanging energy between households, which is not an option in the present legislation. It does however advocate in the favour of microgrids and/or private grids.

11.3. Collective insulation

The objective of this section is to explore the benefits of collective external façade insulation of a set of adjoining houses compared to individual projects. This part of the research focused on the interest of including a collective dimension in such a project.

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[16] Arrêté du Gouvernement de la Région de Bruxelles-Capitale relatif à la promotion de l'électricité verte, Article 34, http://www.ejustice.just.fgov.be/cgi_loi/change_lg.pl?language=fr&la=F&table_name=loi&cn=2015121728

[17] Ibid, Article 41

[18] *http://www.elia.be/fr*

[19] Synergrid, "Synthetic load profiles, slp." http://www.synergrid.be/index.cfm?PageID=16896&language_code=NED,2016. Accessed: 06/05/2016.

Our first step was devoted to identify the best practices for the isolation of facades in general and in Brussels. A majority of experts agree that, in view of the advantages associated with it, it is always necessary to give priority to insulation from the outside when it is possible in relation to insulation from the inside. The choice has therefore been made within the framework of this project to isolate from the outside. Exterior thermal insulation systems are called ETICS ("External Thermal Insulation Composite System"). They consist of different compatible components forming a closed assembly. Next, we showed the specificities of the project studied in our case, as well as the process for the choice of dwellings to be studied within the city block.

In a second step, we detailed the costs that are taken into account in the calculation of project profitability, as well as their variability.

The 2016 Belgian central state & local grants as well as their conditions for granting, are also discussed. Finally, the energy savings that can be expected from the insulation of the façades, as well as the methodology used in this paper to calculate the latter are explained in detail.

We carried out an analysis of the cost-effectiveness of insulation based on a very large number of variables and adopting a series of assumptions. The profitability analysis of individual insulation is done per household. We then compared the case of collective isolation with the individual insulation which delivered three main results:

- While individual projects are never profitable in the different explored scenarios, the achievement of collective insulation can allow a project to be profitable for all the dwellings concerned when optimizing the different parameters. We succeeded to show that collective isolation allows for reductions in the total which can make profitable a project that is never viable when it is undertaken individually.
- There is a large heterogeneity of costs for each individual house involved in a collective insulation project due to both the surface of the façade and its specificity (disparities between dwellings which are due to the ancillary works to be carried out depending on the characteristics of the façade such as the number of windows (involving the replacement of thresholds), or the presence of materials to be stripped. Such heterogeneity is largely due to the high average age of the houses in Brussels and in the chosen city.

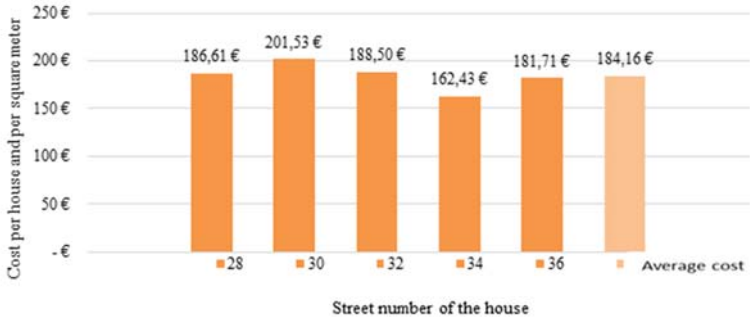

Figure 12: Total insulation cost per house and per m²

In such a collective project, the basic principle is that the more cost-effective facades will compensate those that are not or less. Therefore, one of the success keys for grouping the efforts will be to define upfront the rules for sharing the costs and benefits of the insulation between the dwellings.

- Our study also showed that a collective project makes it easier to use a crowdfunding platform which offers credit opportunities that are more attractive than the usual loans Banks. Given that the method of financing significantly influences the value of the project, the use of such a platform makes it possible to significantly improve the profitability of the insulation project.

Other benefits of making such a project collectively are the strengthening of social cohesion within the neighbourhood, the increased attention and help of the municipality during the administrative procedures related to the project, and a reduction of "thermal bridges" due to the continuity of the insulation between terraced houses.

On the technical side, we also analysed through these various scenarios the thickness of the insulation to be privileged during the insulation of the facades. It shows that the profitability decreases with the thickness of the insulation until no longer be profitable. By combining this aspect with the regulations as well as the conditions for granting premiums, we conclude that a thickness of insulation of 12 cm is optimal.

Finally, we studied the influence of different input variables on profitability, using Monte Carlo method. We highlight in particular that the evolution of energy cost is the variable that will have the greatest impact on the profitability of such a project.

In summary, this part of the research has shown the interest of carrying out the isolation works collectively. These findings are important given the few external facade insulation projects that are now being carried out on a collective basis. The role that local authorities can play in increasing this proportion will be decisive.

11.4. Mobility

Mobility is the topic that was the most frequently pointed out as problematic in the city block of Uccle. We were specifically asked to evaluate solutions for reducing the number of cars though car sharing mechanisms. We focussed on shared electric vehicle for two reasons:

- Contrary to conventional thermal engine vehicles, electric vehicle offer, besides a local reduction of air pollution, an electric consumption and storage capacity which can positively contribute to a global SCB solution if correctly coupled to electricity production (CHP and/or PV).
- Car sharing offers an alternative to the current Western mobility model, which has proven to be unsustainable in a number of ways. The practice of sharing a car offers a realistic alternative, as it addresses the major ecological issues raised by the current model and improves the economic and social efficiency.

In this section we describe the economic modelling of the implementation of an electrical car sharing facility.

The first part of this research consisted developing a method to evaluate, in the current usages of private vehicles, which usages are compatible with car sharing (typically less than 30 minutes). A statistical model was then developed to evaluate the optimum number of vehicles to be introduced into the block, taking into account user requirements. Two approaches were investigated: the "guaranteed availability" approach and the "average waiting time" approach. The first one made it possible to evaluate the necessary number of vehicles (and thus the resulting costs) based on the requirements of the users. The second approach is reverse, expressing the waiting time and the availability on the basis of a predefined number of vehicles.

Next, we provided an economic modelling of the implementation of the electrical car sharing facility in the city block. It gives a breakdown of the costs linked to different possible solutions regarding the implementation of a car sharing facility in the city block, provides a plan for implementing the facility and analyses possible pricing scenarios. Finally an inventory of possible financing solutions adapted to the project of the city block is provided.

After analysing the different alternatives available for the city block two options appeared to be economically, socially and ecologically rational. Either the city block decides to launch the project by itself, or it decides to outsource the cars hiring facility to an existing player active in the market.

If the city block decides to launch the project by itself, it should use the services offered by an external support organisation such as Autopia which offers a series advantages:

- The organization of the car sharing facility is highly facilitated by the use of the tools provided such as the reservation system or a system provided to compute the actual costs to be shared by the participants.
- The risk is shared over a larger population, as the system enables people external to the city block to join the facility easily.
- Another non negligible advantage is the personal car sharing policy offered by Autopia. Thanks to this system, we can not only be assured that every participating member is correctly insured but also be certain that this insurance is perfectly fitted for car sharing to be associated with classical car renting which is important in the case of an accident.
- Autopia also assumes the role of arbitrator between the participants in case of internal conflict or dispute
- Thanks to their negotiations with the municipalities many advantages are put in place for the members of Autopia by the municipalities to encourage car sharing. Those advantages include parking facilities for example.

If the city block inhabitants decide to subcontract, among the firms offering such a product/service, Zen Car should be preferred based on cost and offered services assessment.

Using the real options theory, we succeeded to show that the implementation should ideally be done in two phases: a test phase with an established car sharing company to assess local demand for car sharing and subsequently, if demand turns out to be sufficient, to launch the project by itself.

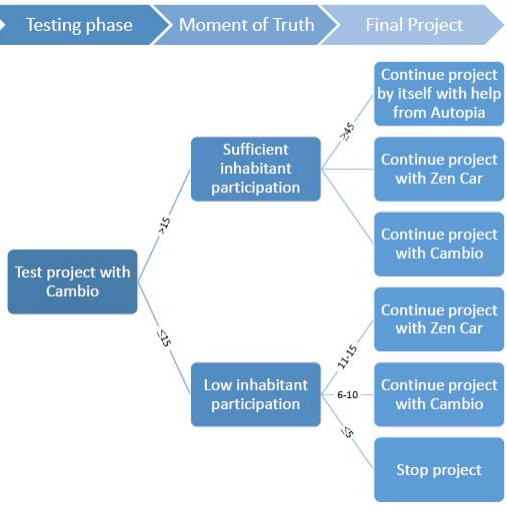

Figure 13: decision tree for the car sharing project based on the real options theory

Pricing the car sharing services should be done carefully. The service should be kept as cheap as possible to encourage the inhabitants to switch their current mobility habits, while being costly enough to discourage long uses of the vehicles, as these uses are incompatible with the fundamental car sharing principles. It is therefore recommended to have a two-part subscription fee. One fixed subscription fee irrespective of the use of the car, and a variable subscription fee discouraging long uses of the car.

Finally many solutions exist when it comes to finance the car sharing facility. The risk profile of the project, the current situation of the European economy and the amount of financing needed for the project tend to keep interest rates down.

In this part of the research, we have been able to show that such a project has a positive expected net present value, raising the interest of all involved parties. As a result, a concrete initiative has been taken by the inhabitants to start such a project in their city block.

12. Discussion and points of improvement of the methodology

The methodology used throughout this study is mainly based on a number of assumptions that each lead to a number of limitations and biased considerations which we want to express for nourishing further investigations on these topics.

12.1. The city block level

The collective dimension considered in the project is the city block, defined as a small area of the city that is surrounded by streets or other public domain limits (railways, rivers, etc.). Most city blocks offer an inner space (gardens, etc.) that is edged by buildings on the street side. Thinking in terms of renovation at the city block level opens thus new opportunities for energy efficiency, sharing and exchanging between people living in the city block. Most city blocks in Brussels contain between 100 and 250 dwellings, a manageable size for such projects.

A common reaction of inhabitants to the city block concept is that inhabitants are better acquainted with their neighbours living in their street - either on the same side or on the opposite side – than inhabitants of the other side of the block, which is most generally another street. This is logically explained by the fact that in most blocks, there is no possible physical communication through the block. In blocks where pathways or public zones exist in the block, this does not occur.

A more important topic seems to be the notion of identity. We regularly noticed that inhabitants share some kind of identity with many other inhabitants of their block or from adjacent blocks. This notion of identity does not map directly on the physical boundaries of the block. We often can across people willing to extend the project to other blocks or, more rarely, suggesting to exclude part of the block in case of high socio-economical heterogeneity.

12.2. Managing the elements

An "element" is defined as any physical element – building, rooms, indoor or outdoor space, infrastructure, equipment or resource – that can be included within a renovation project to increase energy efficiency, environment friendliness, social ties or economic advantages. Over 50 elements were defined and grouped as technical, environmental and social.

Elements are complex. We analysed several aspects related to each element: the flows, the space requirements, the necessary equipment, the maintenance tasks, the possible activities, the various advantages and a number of scenarios when linking elements together.

During our presentations and the coelaboration process, we encountered a number of difficulties with these elements:

- It is impossible during a presentation to present them systematically or in detail. Multiple sessions are necessary to just cover a subset and a lot of time must be allocated to the more complex elements, such as combined heat and power and district heating.
- Although we defined a set of more than 50 elements with a basic technical and financial evaluation, the list is not complete and the evaluations are not easily transposable. New elements should be designed for city blocks having some specificities: parking or traffic congestions, high apartment proportion, low ownership proportion, age of buildings, etc.
- Questions often arose about implementations and investments. Though some general answers can be given, precise responses require an in-depth analysis that we could not always offer due to time constraints.
- The most difficult task is to correctly cover the scenarios. Indeed, some elements that are not financially interesting on their own can become interesting within a scenario. However, during the coelaboration meetings, we did not succeed in obtaining an agreement on a global integrated scenario, as the more complex the scenario is the more discussions it raises.

However, the idea of catalogue seems very useful to trigger discussions and to widen the range of acceptable solutions in the mind of the inhabitants.

12.3. The selection process

The selection process is one of the most critical parts of the project. Indeed, as the SCB concept is not mainstream, it is difficult to evaluate if a given city block, or part of it, will be, with a high probability, wanting to consider SCB proposals. Moreover, the selection process must be very selective as next step (the coelaboration) is very time-consuming and cannot be run on many city blocks in parallel.

To perform the selection we started with a call for proposal (CfP), then extracted a short list based on score cards using data that could be be gathered. The final step was a evaluating how the inhabitants of the short-listed blocks reacted to the SCB proposal.

Though this showed to be successful, we see a number of shortcomings for the CfP:

- We could not evaluate the proportion of city blocks that were reached by the advertisement and the mailing of the CfP. Many blocks were "de facto" excluded from the CfP; firstly because the CfP was only available in French, secondly because it was relayed by a limited number of municipalities and thirdly because the CfP was to be answered through a short questionnaire only available on a web site, thus excluding a part of the population.
- The communication about the CfP and the available SCB documentation could have been simplified and advertisement would have benefitted from a wider range of mass media channels.
- We would advise to adapt the CfP with to different city block types, ideally based on the segmentation (section 4), but at least taking into account the difference between blocks that are mainly owner-occupied or occupied by tenants.

However, we believe these points would only affect the number of answers to the CfP though, from our viewpoint, the most critical part is the selection within the set of answers. All candidates were contacted and information meetings were to be set up in collaboration with the person (or groups of persons) that filled in the CfP. When this could not be done, the candidate was eliminated. We estimated that the best candidate was the block for which the largest number of inhabitants attended to the meetings and answered positively a questionnaire. Three months were allocated to this process. Two remarks can be done on this process:

- The metric used is one that evaluates the attitude, not the behaviour. We therefore select blocks for which there is a large number of interested people, which is not sufficient to evaluate if this will result in future actions.
- An in-depth study of the inhabitants should be done as to understand if there are other aspects that can have impact on the social dynamics of the inhabitants, such as age structure, working/non-working, children, religion, non-profit organisations, representativeness of leaders, etc. Having had many discussions with inhabitants during the remaining two-year of the project, we believe that, had we done more in-depth enquiries, other neighbouring blocks could have been more dynamic.

12.4. Stakeholders

We primarily worked with inhabitants, the ULB bringing information from external stakeholders. Though this allowed us to build a strong relation of mutual trust, we should have introduced other stakeholders during the coelaboration meetings: architects, contractors, public authorities, banks, third party investors, etc. We also felt that the support of the municipality would have been beneficial, which was lacking in the city block of Uccle.

12.5. Moving from coelaboration to action

The last point that deserves special attention is the transmission of the sense of ownership of the project. Initiated by the university it must be transmitted to working groups mainly composed of inhabitants.

It is interesting to consider three specific points of interactions from the viewpoint of the planned behaviour theory of Azjen: the answer to the CfP, the brainstorming and coelaboration process and the constitution of working groups at the end of the project. Indeed, these particular moments allow evaluating the attitude-behaviour gap related to SCB.

Answering to the CfP is clearly a behavioural action but it only involves very small groups of person (between one and three). The brainstorming and coelaboration meetings give us an approximation of the proportion of the population having a positive or negative attitude related to the project. As these meeting no not require much involvement from the attendees - besides physical presence -, it is not appropriate as to measure up to what extent, attendees are ready to get strongly involved in the project. Finally, the creation of the working groups is a good proxy for evaluation the number of people having a strong drive to continue the project.

For the city block of Uccle, the CfP was filled in by 2 persons, the meetings were attended by approximately 10% of the inhabitants and only 8 persons were willing to get really implied in working groups.

This allows us to draw the following conclusions as to be for efficient for the selection process:

- Answering to the CfP should only be authorized for small groups of inhabitants, for example, composed of minimum 3 persons. More time should be allocated for the answering period as to allow the emergence of the groups.
- The brainstorming meetings should have as additional objective the early identification of persons ready to get involved in working groups. These meetings are also well adapted for understanding the social dynamics of the city block and set up groups accordingly.
- Working groups should be set up in parallel with the coelaboration meetings. This would allow an earlier appropriation of the projects and more active participation.
- Working groups should also include, right from the beginning, other stakeholders than the sole inhabitants. We believe that technical partners (industry, architects, energy services, etc.) and financial services (third party investors, crowed funding platforms) would help in the dynamics of the working groups.

13. Conclusions and further research

This research started with the idea that collective renovation of dwellings in a city such as Brussels can bring multiple benefits in terms of energy efficiency, cost reduction and social ties, if correctly implemented on small geographical areas.

The Smart City Block (SCB) project works on the "à priori" level of a city block, including a number of dwellings (houses, apartments, commerce and/or offices), that are delimited by public spaces, typically pathways, streets, railways or rivers. The concept of city block could be softened and extended with that a "neighbourhood identity".

A first theoretical part of the project allowed us to categorise city block of the Brussel Capital Region based on a wide range of parameters. 14 types of city block could be identified, showing enormous difference between different parts of the city that is tightly correlated with socio-economical index. On the high-end, underpopulated large detached house where global energy efficiency is low but where there is no willingness to renovate for other reasons than comfort or aesthetics. On the other extreme, the old housing with high inhabitant density and low ownership

rates concentrate the fuel-poor population. About a half of the city blocks is composed of row houses and apartment blocks of 3 to 5 stories. The quality of the typology could be increased by integrating more recent and other sources of data (e.g. PEB data, SME activity, population, NGO's, local associations, etc.). Similarly, more data could be extracted from GIS systems such as Google maps, Google Street view and the UrbIs system.

The list of 50 elements developed for the project is a good base for presenting the project to the population. However, some aspects that cannot be considered as elements in the sense they were defined in the project should also be included: security, intergenerational services, children activities, etc. Simplified presentation cards and/or games could be developed as to ease coelaboration meetings.

Though the surveys we carried out cannot be considered as representative, we noticed an almost zero-respond rate in the very healthy and the very poor parts of Brussels. Of the "middle-class" parts of the city, about 20% of the surveyed persons expressed a positive attitude to the SCB project. The attitude is more positive for elements that are well-know and perceived as simple. The brainstorming and coelaboration meetings have educational impact and increases participant's interest in more complex items.

Subsidies and other financial facilities offered by public authorities are essentially oriented towards households, either landlords or tenants. No significant incentives explicitly exist at the level of collective renovation, which we feel as a shortcoming in energy policies and urban renovation. However, financial incentives - although a very strong incentive - are not the only ones that can be used to promote projects such as SCB. Non-financial advantages related to parking or social services and complementary currency systems (e.g. LETS) could also be used.

Economic and financial aspects are nonetheless most important and need to be evaluated precisely during the meetings. Most owners will refuse any solution for which they have the impressions of additional costs. The financing of the solutions must also be carefully described. This point also advocates for including private (installers, banks, energy service companies, architects, etc.) and public stakeholders (municipalities, region, academics) during the brainstorming and coelaboration meetings.

One of the main difficulties during the meetings is the number of iterations required to select the elements adapted to the city block. Ideally for each iteration a technical, economic and financial simulation should be presented which would require a complex and complete modelling. The main complexity arises from the integration of linked elements, especially when heat or electricity flows are involved and shared. CHP, district heating, photovoltaics, shared laundrette, and shared electric vehicles are all elements for which benefits increases if correctly integrated with one another.

The selection of city blocks remains a critical point. The method used allowed us to find a block to carry out our project but could be improved. On one side, the systematic identification of adequate (from the technical and economic viewpoint) could be achieved by a dedicated tool using a number of parameters available in existing databases or that can be easily be gathered. On the other side, the Call-for-proposal approach should be further developed as to get a more detailed image of the social dynamics.

The modelling clearly showed the technical and economic benefits that could be obtained by sharing heat and electricity. This however implies private energy networks which are not authorised under today's legislation (unless derogation is obtained). We however believe that the evolution of the energy sector will authorise this in the future as a consequence of the smart grid development. Hence, we would definitely propose further research, both theoretical and applied, in an existing city block.