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Stakeholders' engagement in the co-design of energy conservation interventions: The case of the Energy Living Lab

Thèse de doctorat

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Docteur en Sciences de l'Environnement par :

Joelle Mastelic, Licence en Management, HEC Lausanne.

Jury:

- Dr Dominique Bourg, UniL, Directeur
- Dr Stéphane Genoud, HES-SO, Expert
- Dr Emmanuel Fragnière, HES-SO, Expert
- Dr Jordi Colobrans, University of Barcelona, Expert
- Dr Christophe Sempels, ImmaTerra, Expert

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IMPRIMATUR

L'Engagement des parties prenantes dans le co-design d'interventions pour réduire la consommation d'énergie : le cas de l'Energy Living Lab

Résumé

Comment atteindre l'efficacité énergétique dans les bâtiments à faible consommation ? Souvent, dans la littérature on constate une analyse séparée des interventions sur les comportements, sur les artefacts techniques ou sur les normes. Les trois composantes d'un système socio-technique sont en interaction et il s'agit de modifier le système complexe dans son ensemble. Cette thèse pluridisciplinaire analyse les dimensions techniques, économiques et sociales de la performance énergétique des bâtiments basse consommation afin d'agir sur le système avec une intervention regroupant marketing social et Living Lab (LL). Comment les services énergétiques sont-ils perçus par les consommateurs dans les bâtiments basse consommation ? Sont-ils prêts à co-concevoir des interventions de conservation d'énergie ? Est-ce que ces idées créent de la valeur ? Comment intégrer différentes parties prenantes dans le co-design d'une intervention d'économie d'énergie ? Existe-t-il un «écart de performance sociale» des services énergétiques ? Comment le mesurer ? Cette thèse est basée sur deux projets de recherche, le projet pilote Energy Living Lab et le projet UserGap utilisant les multiméthodes séquentielles. Une enquête empirique permet de recueillir des données sociodémographiques. Des entrevues qualitatives en face à face font ressortir les obstacles aux pratiques de conservation d'énergie. Ensuite, une étude de cas analyse le processus de crowdsourcing et mesure la qualité des idées générées. Une deuxième étude de cas analyse l'intégration des différentes parties prenantes dans la co-conception d'un système de gestion de l'énergie du bâtiment. Puis, un nouveau modèle conceptuel sur l'écart de performance énergétique est induit à partir des données. Nous avons constaté que les consommateurs ne perçoivent pas la qualité des services énergétiques tant que la qualité est bonne. Les services énergétiques ne sont pas fortement liés à la satisfaction de vivre dans des bâtiments à basse consommation. S'ils sont intégrés dans le co-design de solutions, les parties prenantes ont des idées qui créent une valeur sociétale et managériale. Les LLs agissent comme des catalyseurs, des intermédiaires d'innovation pour orchestrer le co-design dans un écosystème d'acteurs. La question clé de la « performance sociale » pourrait être mesurée par la qualité perçue des services énergétiques. Les multi-méthodes séquentielles utilisées dans cette thèse ne sont pas faciles à reproduire. Les résultats sont limités au secteur du bâtiment à basse consommation. Les études de cas n'ont pas pour but d'être généralisées mais sont exploratoires. Elles devraient être suivies d'une quasi-expérimentation pour généraliser les résultats dans d'autres régions et mesurer l'impact du processus de co-design. La recommandation à la société de construction, au fournisseur d'énergie et de label énergétique est d'intégrer les parties prenantes dans la co-conception des bâtiments à basse consommation et des interventions de conservation de l'énergie. Une boucle de feedback pourrait réduire l'écart de performance des bâtiments existants et une boucle de feedforward pourrait aider à la conception des futurs services énergétiques. Les implications sociétales pourraient être la diminution des émissions de CO^2, une meilleure intégration du consommateur comme co-créateur de valeur. L'intégration des parties prenantes pourrait également augmenter l'adoption sociale. Cette thèse explore le processus de co-design dans le secteur des services énergétiques dans les bâtiments à basse consommation. Elle propose un nouveau modèle conceptuel pour comprendre l'écart de performance énergétique. La méthode du marketing social dans un LL permet de développer un nouveau processus d'innovation dans le secteur des services énergétiques.

Stakeholders' engagement in the co-design of energy conservation interventions: The case of the Energy Living Lab

Abstract

How is energy efficiency in low consumption buildings achieved? In the literature, there is often a separation between interventions on behaviors, on technical artifacts or on norms. The three components of a socio-technical system interact, and it is a question of modifying the complex system as a whole. In this pluridisciplinary thesis, we propose to analyze the technical, economic and social dimensions of the energy performance of low consumption buildings and to act on the system with an intervention combining social marketing and a Living Lab. How are energy services perceived by consumers in low consumption buildings? Are they ready to co-design energy conservation interventions? Do these ideas create value? How does one integrate different stakeholders in the co-design of an energy conservation intervention? Is there a "social performance gap" in energy services? How does one measure it? This thesis is based on two research projects, the Energy Living Lab pilot project and the UserGap project using sequential multi-methods. An empirical survey collects socio-demographic data. Qualitative face-to-face interviews highlight barriers to energy conservation practices. Next, a case study analyses the crowdsourcing process and measures the quality of the ideas generated. A second case study analyses the integration of different stakeholders in the co-design of a building energy management system. Then, a new conceptual model on the energy performance gap is induced from the data. We have found that consumers do not perceive the quality of energy services as long as the quality is good. Energy services are not strongly related to the satisfaction of living in low consumption buildings. If integrated into a co-design process, stakeholders have ideas that create societal and managerial value. Living Labs act as catalysts, as innovation intermediaries to orchestrate the co-design process in an ecosystem of actors. The key issue of "social performance" could be measured by the perceived quality of energy services. The multi-sequential methods used in this thesis are not easy to reproduce. The results are limited to the low consumption building sector. The case study method is not intended to be generalized but is exploratory. They should be followed by quasi-experimentation to generalize the results to other regions and measure the impact of co-design. The recommendation to the construction company, energy supplier and energy label certifier is to include stakeholders in the co-design of low consumption buildings and energy conservation interventions. A feedback loop could reduce the performance gap of existing buildings and a feedforward loop could help design future energy services. The societal implications could be the reduction of CO^2 emissions and a better integration of the consumer as a co-creator of value. Inclusion of stakeholders could also increase social adoption. This thesis explores the co-design process in the energy services sector in low consumption buildings. It proposes a new conceptual model for understanding the energy performance gap. The method of social marketing in Living Labs makes it possible to develop a new process of innovation in the energy services sector.

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All these people, as well as those who are not mentioned above but who have contributed to providing a supportive environment, are warmly thanked. This thesis is about people, co-creation of value and trust in human nature. We, marketers, have contributed to the environmental problems that the earth is currently experiencing. With social marketing, we can also help find solutions to current problems. After a very classical education in marketing and a transition to multinationals, I have the chance to make my small contribution with these applied researches. As Hastings said in his paper, “*I am a rebel with a cause*” (2017).

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III. List of abreviations

AI	Agile Innovation
BEMS	Building Energy Management System
BMC	Business Model Canvas
CBSM	Community Based Social Marketing
CREST	Competence Center for Research in Energy, Society and Transition
DHS	District Heating System
EC	European Commission
EE	Energy Efficiency
EEA	European Environment Agency
ENoLL	European Network of Living Labs
EPBD	Energy Performance of Buildings Directive
EPG	Energy Performance Gap
ESCO	Energy Service Company
FMCG	Fast Moving Consumer Goods
HES-SO	University of Applied Science Western Switzerland
KPI	Key Performance Index
LbM	Linky by Makers
ELL	Energy Living Lab
LL	Living Lab
LLIP	Living Lab Integrative Process
OI	Open Innovation
PPPP	Public Private People Partnership
SCCER	Swiss Competence Centers for Energy Research
SDL	Service Dominant Logic
SFOE	Swiss Federal Office for Energy
ST-Sytem	Socio-technical System
UPC	University Polytechnic of Catalonia

Chapter 1

Introduction: context, research questions, literature review and methods

This chapter will introduce the context of energy performance in low consumption buildings. Why is it important to work on this theme? Which questions remain open? The main research questions will be proposed and the key terms of co-design, social marketing and energy conservation will be defined from the literature and linked together. The epistemological paradigms in the pluridisciplinary team will be expressed, as well as the main methods used in the thesis.

1.1. Context: energy performance in low consumption buildings

Europe is facing an energy transition based on two main pillars: (1) energy efficiency, and (2) the development of renewable energies. Approx. 40% of the energy consumption is related to the building sector in Europe (EC, 2013). Efforts are made to achieve ambitious goals: "*by 31 December 2020, all new buildings are nearly zero-energy buildings"* (European Commission, 2013). Switzerland is not integrated politically with Europe but is geographically at the center of the continent. The energy context is different, but the objectives are similar. The Swiss Federal Council has developed a strategy called Energy Strategy 2050. After the Fukushima accident, Switzerland decided to go away from nuclear power and promote renewable energies. One of the goals of this strategy is also to decrease the total energy consumption by 2050. Three areas are at the center of this strategy: (1) increase in the capacity of hydropower (2) use of other renewable energy sources, (3) higher degree of **energy efficiency in buildings**, appliances and the transport sector (SFOE, 2016). The thesis will focus on the third element: energy efficiency in the building sector. A distinction can be made between high consumption buildings and low consumption buildings: an effort is proposed to renovate the high consumption buildings and apply energy efficiency techniques. This constitutes a big challenge today in the old continent, requiring high investments' intensity but it will be outside the scope of this thesis, which is focused on the second part: understanding the underperformance of low consumption buildings and acting on it with an intervention.

1.1.1 Research focused on energy services

To support research activities linked to this energy transition, eight Swiss Competence Centers for Energy Research (SCCER) have been launched by the Confederation in 2013. One of the SCCERs concentrates its effort on non-technical thematics such as law, economics, and innovation. It is called the Competence Center for Research in Energy, Society and Transition (CREST). This PhD thesis is anchored in work package two of this competence center: "Change of Behavior." This research group composed of psychologists, sociologists, economists and marketers focuses on the individual and the factors that influence the individual energy consumption. CREST states that: "*As individuals and households do not demand (in most cases) energy directly but ask for* ***energy services****, analyzing 'potential changes in consumption patterns' includes analyzing "potential changes in demand" and "potential alternatives in* *delivering the services*" (CREST, 2016). Design and operation of energy services in the low consumption buildings will be the core of this pluridisciplinary thesis.

A definition of "energy services" is proposed by Fell: ***"Energy services are those functions performed using energy which are means to obtain or facilitate desired end services or states." (2017).*** In this thesis, different energy services provided in low consumption buildings will be studied such as heating, lighting, washing (body, laundry, dishes) ... The author stands that more attention is needed on energy services and on the value delivery process of the service. We mobilize the Service Dominant Logic paradigm (Vargo & Lusch, 2004). The product is seen as a vehicle that brings this value to the consumers. This thesis is at the interface of production and consumption in low consumption buildings.

1.1.2 The building as a complex socio-technical system

In this thesis, the building is perceived as a complex system composed of (1) Human actors, organisations, social groups (2) Rules, institutions and (3) Socio-technical systems interacting (Geels, 2004), as shown in Figure 1.

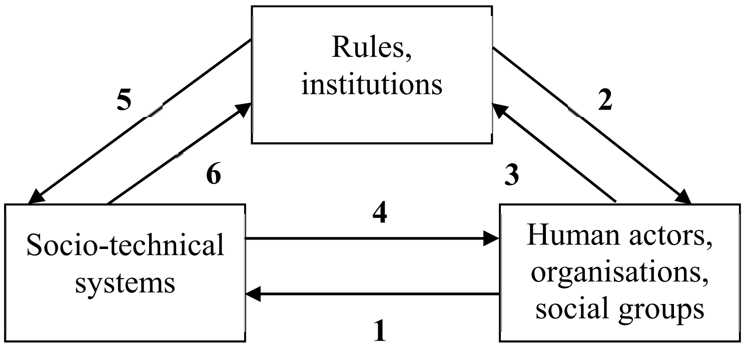

Figure 1. Three interrelated analytic dimensions, adapted from Geels (2004).

1. *"ST-systems do not work on their own, but through the involvement of human actors, an organisation.*
2. *Actors operate in the context of rules. Their perceptions, and (inter)actions are guided by rules.*
3. *Actors carry and (re)produce the rules.*
4. *ST-systems, artefacts and material conditions form a context for action. They enable and constrain (actor-network theory).*
5. *Rules are not just embedded in heads of actors, but also in artefacts (eg. Latour's script).*
6. *ST-systems, artefacts and material conditions shape rules, frames, standards etc. "Interpretative flexibility" is constrained by technical/material possibilities."*

The richness of a pluridisciplinary applied research project is to gain different specialised as well as “naïve” perspectives on the three parts of the system. Engineers are specialised on the artefacts, the building itself, the appliances, the engineering and architectural standards. Marketeers are specialised in the human attitudes and behaviour, on the understanding of the tacit social norms. Economists offer a different perspective of rational decision making based on monetary value, analysis of the variables influencing the system with econometric analysis.

If we focus on **rules**, Scott proposes a typology of rules in a system as in Table 1: regulative, normative, and cognitive (in Geels, 2004, p. 904). These rules are written or tacit, depending on the type of rules. They influence how the actors use energy and how the technical artefacts are designed and operate.

	Regulative	**Normative**	**Cognitive**
Examples	Formal rules, laws, sanctions, incentive structures, governance systems, power systems, protocols, standards, procedures	Values, norms, role expectations, authority systems, duty, codes of conduct	Priorities, problem agendas, beliefs, bodies of knowledge (paradigms), models of reality, categories, classifications, jargon/language, search heuristics
Basis of compliance	Expedience	Social obligation	Taken for granted
Logic	Instrumentality (creating stability, “rules of the game”)	Appropriateness, becoming part of the group (“how we do things”)	Orthodoxy (shared ideas, concepts)
Basis of legitimacy	Legally sanctioned	Morally governed	Culturally supported, conceptually correct

Table 1. Three kind of rules/institutions, adapted from Scott in Geels (2004).

In this applied research, numerous written and tacit rules exist. Examples of written regulative standards apply for the construction of a low consumption building such as in Switzerland the SIA standard 380/1 on thermal requirements for heating and SIA 380/4 on electrical energy use in the building. These are the main standards which will be studied in the context of swiss low consumption buildings. The technical artefacts are also programmed with normative rules. For instance, the Building Energy Management System is programmed to optimise the operation of the energy services: ventilating, lighting, heating. Cognitive rules are also embedded in the artefacts and in the actors influencing the decision-making process. Cognitive rules are often tacit and difficult to make it emerge at the surface. Qualitative research methods will be used to deepen the understanding of these cognitive rules. It is an important contribution of the social sciences to the emergence of latent cognitive social norms.

If we focus on the **actors**, the energy consumers are named “occupants” in the technical literature. Engineers and architects separate two main phases in the construction of a low consumption building: “pre-occupancy,” when the building is empty; and “post-occupancy,” when the occupants are in the building as illustrated in Figure 2.

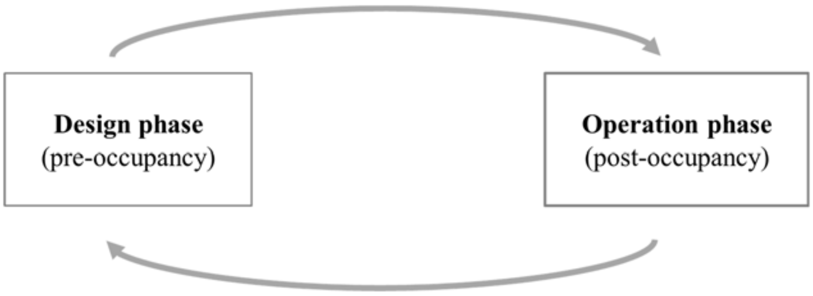

Figure 2. Two distinct phases of the building’s life cycle.

In this thesis, we stand that understanding the patterns used by the “occupants” when they consume energy in the operation phase and trying to change these patterns (“behaviour change” researches) is not enough to understand the complex system and act upon it. From our perspective, without understanding the interactions with the technical artefacts and the rules, we do not have the “full picture” of the socio-technical system be able to develop an intervention and to act on energy performance (Geels, 2004). In this thesis, the focus is not only on “behaviour change” but on “**system change**”. Integrating the stakeholders in the operation phase is interesting for optimisation purposes. More interesting is to gain feedback for future design of energy services.

Figure 3. Living Lab integrative intervention.

As shown in Figure 3, the intervention on the system could integrate: (1) actions to change the actors’ practices, (2) actions to change the rules and institutions and (3) actions to change the technical artefacts, material conditions. A combination of these three types of actions seems from our research first intuitions suitable and needs to be tested in this thesis.

1.1.3 Energy performance in residential buildings

In Switzerland, **households' energy consumption** accounts for 32.2% of total energy consumption; it is the greatest consumption before industry: 30.9%, services: 27.1%, transport: 8.1% and agriculture: 1.7% (Bundesamt für Energie, 2016). Understanding how to increase energy efficiency in residential buildings could have a major impact toward the goal of the Federal Council in the "Energy Strategy 2050." Energy consumption is decreasing in the industry sector and increasing in the residential sector, emphasizing the needs for energy efficiency programs in this domain. In the building sector, many challenges remain open, such as the energy performance gap. There is often a gap between **planned energy performance (pre-occupancy)** and **actual energy performance (post-occupancy)**, even in low consumption buildings, part of it is linked with the "occupants' behaviour" as detailed by Burmann et al (2014) in the Figure 4, when analysing the Energy Performance of Building Directive (EPBD). This gap is not fully explained in the literature.

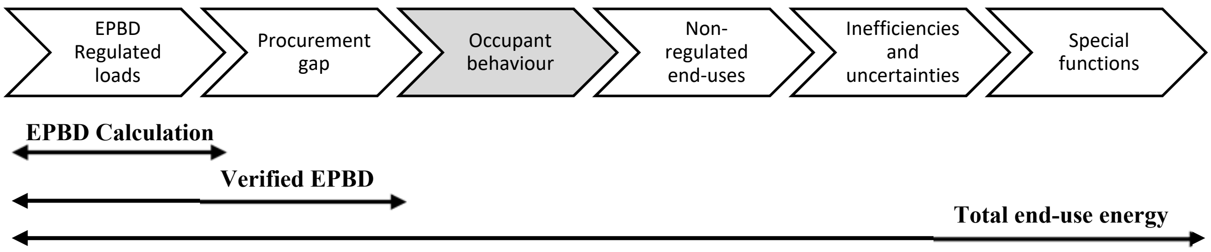

Figure 4 Energy performance gap, adapted from Burmann et al. (2014).

What are the measures to increase energy efficiency and to decrease the performance gap in the residential buildings? This question has already been studied for decades. For instance, in 2006, a study concentrated on the willingness to pay for energy savings measures in residential buildings in Switzerland (Banfi, Farsi, Filippini, and Jakob). The research team has conducted a choice experiment with two samples for rented apartments and home owners. They concluded that there is a significant willingness to pay for energy efficiency. They have based their study on stated preferences because revealed preference data *"is only scarcely available since the market of energy-efficient houses is still small."* At that time, the recommended measures were to support communication and information for decision makers *"namely consumers, investors and financial institutions."* The data on energy efficiency, thanks to the deployment of smart meters, are becoming more accessible today and it is possible to observe consumers' behaviors in the context and not through "proxy variables" such as attitudes toward energy consumption.

This is what the research team proposes in this thesis: study behaviors with socio-demographic data coming from surveys and consumption data coming from smart meters and utility bills.

Today, numerous researches have shown that there is an "**attitude-behaviour gap**" in the environmental sector and that researches only based on declarative data on attitudes do not reflect the reality of individual behaviours (Kollmuss & Agyeman, 2002). Collecting data through surveys is interesting because one can obtain socio-demographic data or compare attitudes (such as social norms) and behaviors measured by, for instance, smart meter data. The author is against using survey data collecting attitudes as a proxy for behaviors as it could generate serious discrepancies. Other methods and processes need to be developed.

1.1.4 Community based social marketing and co-design

In 2013, the European Environment Agency conducted a meta-analysis of different types of measures to increase energy efficiency. A report titled *"Achieving energy efficiency through behavior change: what does it take?"* sums up the impact of the different measures and their recommendations regarding future energy efficiency programs. In their conclusion, one of the recommendations was to **integrate different stakeholders** in the design and the test of energy efficiency measures or programs (EEA, 2016, p. 43). They also recommend combining different types of measures such as smart meters to inform the residents of their energy consumption, programs based on social practices and on community engagement. **How can the different stakeholders engage in the co-design of energy conservation interventions?** This is precisely what the author intends to better understand, as the literature does not answer these questions.

This type of energy efficiency programs involving different stakeholders is also proposed by social psychologists such as McKenzie-Mohr. He conducted a literature review in 2000 that demonstrates, with numerous examples, that an "attitude-behavior approach" based on information intensive campaigns has little or no effect on behavior. The campaigns based only on an "economic self-interest approach" does not affect the behavior in the long run, either.

A clear obstacle to energy efficiency is the energy cost, which is low at the moment, compared to the price of energy efficiency technologies. The return time should be as short as possible and a too long return time prohibits investment in low consumption technologies. Interventions only based on price incentives seem insufficient.

McKenzie-Mohr proposes an alternative approach called “Community based social marketing”:

*“**Community-based social marketing (CBSM)** merges knowledge from psychology with expertise from social marketing. Social marketing emphasizes that effective program design begins with understanding the **barriers** people perceive to engaging in an activity.” “Social marketing also underscores the importance of strategically delivering programs so that they **target specific segments** of the public and overcome the barriers to this segment’s engaging in the behavior.» (2000)*

His method follows five steps as shown in Figure 5: (1) Selecting a behavior, (2) Identifying barriers and benefits, (3) Designing strategies, (4) Piloting, (5) Broad-scale implementation and evaluation.

Figure 5. Design process of an intervention, adapted from McKenzie-Mohr (2000).

McKenzie-Mohr declares his goal is to give access to scientific literature to energy planners. It could be considered as a “top down approach” driven by professional planners designing and implementing an energy efficiency plan. In both Energy Living Lab (ELL) and UserGap projects, the research teams propose a “**bottom up approach**” of co-designing the intervention with the stakeholders. The hypothesis is that a “bottom up approach” would better address the actual barriers and permit to develop an energy efficiency plan closer to the needs of the stakeholders. It could increase social acceptance of the plan as well.

We would like to test the CBSM process in combination with co-design process in a Living Lab setting: *“Living Labs (LLs) are defined as user-centered, open innovation ecosystems based on systematic user co-creation approach, integrating research and innovation processes in real life communities and settings”* (ENoLL, 2018). The second chapter is dedicated to explaining what a LL is, what are the criteria that best describe this phenomenon, how to keep it alive on the long run. The example of the Energy Living Lab is also used in a case study. The pilot project serves as a basis to define the main concepts and to propose a business model.

1.2. Research questions: role of co-design toward energy performance

Researches studying co-design in Living Labs have been mainly conducted in sectors such as health, tourism, regional development… Few papers describe the use of this participative method for the design and operation of energy services. The purpose of this research is to test this method in the energy sector and understand how to integrate different types of stakeholders to co-design energy conservation interventions. We can formulate the research questions as follows: **Is the co-design method used in LLs transferable to the energy sector? How to engage the key stakeholders in the co-design process of an energy conservation plan? What would be the impact on energy performance gap?**

1.2.1 Aim and objectives: to understand the role of co-design on energy performance

For clarity, Wacker proposes to answer basic questions (1998), as in Table 2 below:

Questions	Answers applied to this thesis
WHO	The key stakeholders of the Public Private People Partnership (PPPP)
WHAT	Co-design of energy services and energy conservation interventions
WHEN	During the energy transition, with advanced building technology
WHERE	In low consumption buildings, in Switzerland, in a LL setting
HOW	With co-design and community-based social marketing methods
WHY	To reduce the energy performance gap (dependant variable)
SHOULD/ COULD/ WOULD	We should integrate the key stakeholders in the co-design of an energy conservation intervention. Then we could reduce the energy performance gap and it would generate positive environmental and social impact.

Table 2. Answers to basic research questions, adapted from Wackers (1998).

Figure 6 represents schematically what the autor intends to study in this thesis:

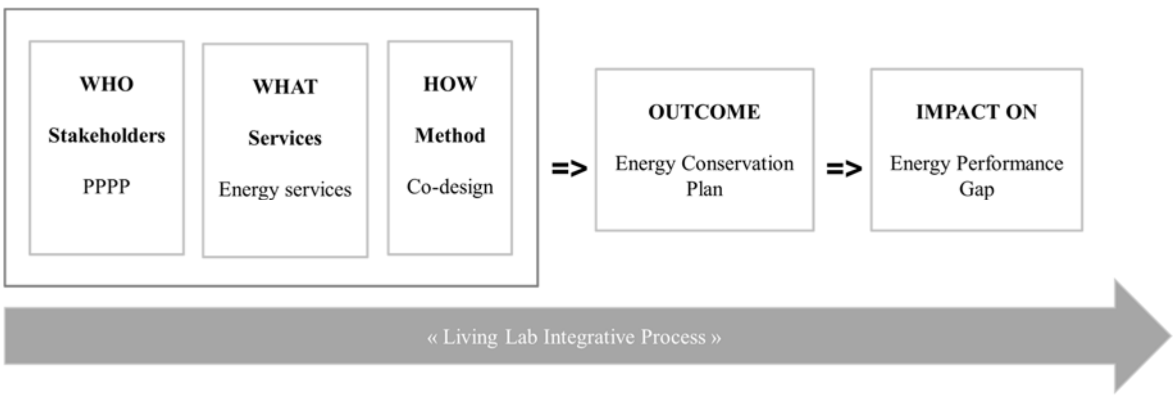

Figure 6. Main constructs of the research design.

1.3. Definition of key concepts: co-design, energy conservation, social marketing

The aim of this section is to **define the main concepts** used in the thesis. Different disciplines study how to design an energy conservation intervention. Due to the amount of literature, it would not be realistic to be exhaustive; the main purpose is to define the terms and frame the research questions. The structure of the chapter is as follows: the method to review the literature will be detailed then the definition of the different terms and the links between the terms at the intersections of the research streams will follow.

1.3.1 Method to review the literature

To review the existing literature, a brainstorming has been done on key words, after a first exploratory literature review. Then, the keywords have been grouped in sub-thematics with a relevance tree. The main key words have generated a new literature research, as proposed by Saunders et al. (2016, p. 73). The following keywords have been used: “co?design” (the sign “?” is used to consider different orthography), “energy conservation” and “social marketing.” The online research tool used is Google scholar, the range is from 2000 to 2018, and the date of search is 20 April 2018. A summary of the results is illustrated in Figure 7.

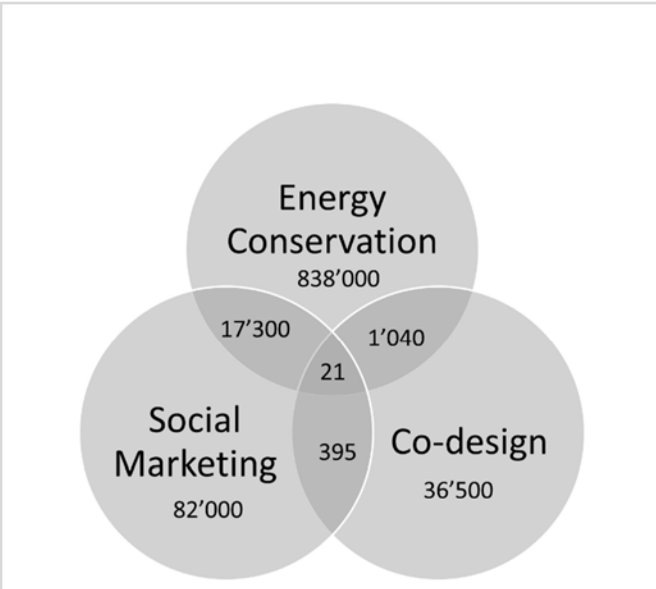

Figure 7. Key words used to search the existing literature.

The difficulty and richness of this research is its positioning at the intersection of several disciplines with different paradigms (from positivism to constructivism) and different methods (qualitative and quantitative), which complicates and enriches the analysis of the literature. An enormous amount of literature exists on the three key words taken separately; however, there are few papers at the intersection of the different thematics. Most of the literature will be presented in the following chapters, in each scientific article. In order to define the terms of the research and to frame the research questions, a brief summary is proposed in this introductive chapter. LL is a recent concept and it is not well established as a literature stream. For this reason, we have not used the term "Living Lab" as a key word of the literature review but we have used instead key words reflecting established literature streams. We consider LL as a **phenomenon**: "*a fact or event of scientific interest susceptible to scientific description and explanation*."[1] The second chapter is dedicated to define what a LL is, its main characteristics and what are the success factors for its longevity.

In the following sections, the concepts will be defined from the literature and a combination of the different concepts will be proposed. The studied phenomena is the Energy Living Lab and its potential impact on the energy performance gap. In the Lab, a co-design process is applied to develop an energy conservation plan with the stakeholders. The plan is the outcome of the co-design process. At the end of the co-design process, a social marketing intervention will be performed to test the impact of the plan on energy performance gap.

1.3.2 How to define « co-design »?

The terms co-design and co-creation are "portmanteau" words with polysemy, abundantly used in the innovation literature. A clarification of the meaning of the two concepts and a semantic differentiation seems important in this thesis, which mobilizes them strongly.

Before going on to explore the scientific literature that defines them, a passage through the dictionary seems to be an important first step. To define "co-design", the word "design" should be defined first. According to the Webster dictionary[2], the term "**design**" means: "(1) to create, fashion, execute, or construct according to plan", or (2) **"**to conceive and plan out in the mind, to have as a purpose, to devise for a specific function or end." This definition does not help to

[1] https://www.merriam-webster.com/dictionary/phenomenon
[2] https://www.merriam-webster.com/dictionary/design

clarify the difference between design and creation, because they define the term "design" in reference with the term "create". Interesting to mention, this definition contains the term "construct"… (f.i. an artefact), not limiting design to the upper phase of the innovation process (ideation, prototyping). With this definition, co-production could be part of a co-design process. The link with the plan is also of value in this thesis focused on energy conservation planning. One can design an intervention according to the EE plan or one can design the EE plan itself and then design and operate an intervention in the low consumption buildings. The notion of "function" and "end" are also interesting as these key words are mobilized in the definition of "energy services" discussed in the next section.

What does the prefix "co-" stand for? From the same dictionary[3], "co-" is defined as: *"(1) with ; together ; joint ; jointly (f.i. coexist, coheir), (2) in or to the same degree (f.i. coextensive), (3) a. one that is associated in an action with another (f.i. coauthor, coworker), b. having a usually lesser share in duty or responsibility (f.i. copilot).*"

In this thesis, based on the empowerment of the stakeholders, the author sees the term "co-" as in definition (1) *together, jointly (2) in or to the same degree* and (3) a. *one that is associated in an action with another*. The different stakeholders will perform the action of jointly developing an energy conservation plan for the neighborhood. It is not aligned with definition (3) b. *having usually a lesser share in duty of responsibility*: stakeholders are considered on an equal footing in LL ecosystems of actors.

After this first phase of concept definition from the dictionary, it is time to analyze the scientific literature to define the key term "co-design". Sanders and Stappers, researchers in the design discipline, have contributed to the development of the scientific definition of co-design with their seminal paper "*Co-creation and the new landscapes of design*" (2008). They define **co-design** in reference to co-creation:

[3] https://www.merriam-webster.com/dictionary/co

“The terms **co-design** *and* **co-creation** *are today often confused and/or treated synonymously with one another. Opinions about* **who** *should be involved in these collective acts of creativity,* **when***, and in* **what** *role vary widely. […] The authors take co-creation to refer to any act of collective creativity, i.e. creativity that is shared by two or more people. Co-creation is a very broad term” […] “By co-design we indicate* **collective creativity** *as it is applied across the whole span of a design process* […] Thus, *co-design is a specific instance of co-creation. […] We use co-design in a broader sense to refer to* ***the creativity of designers and people not trained in design working together in the design development process****.* (2008, p. 3)

In this thesis, stakeholders not trained in energy conservation planning will be integrated together with professional planners in a creativity process to co-design an intervention. The different phases of co-design will be presented below. In a LL approach, the stakeholders are integrated at the beginning of the design development process, in the “**fuzzy front end**” as termed by Sanders and Stappers (2008), as illustrated in Figure 8.

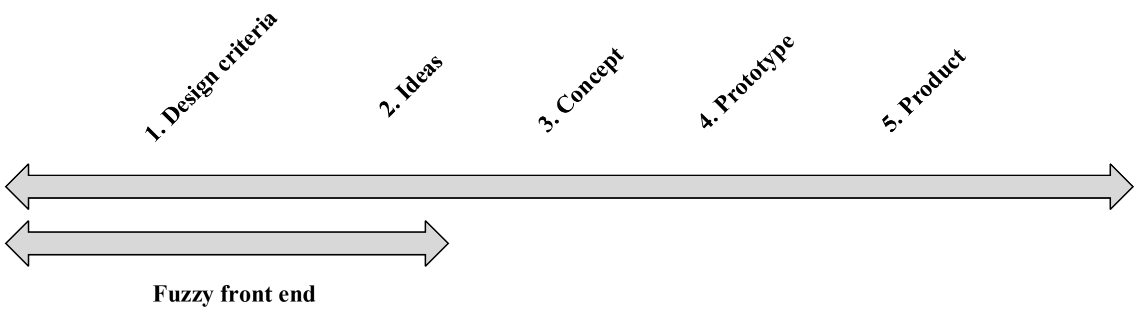

Figure 8. Co-design process, adapted from Sanders (2008).

Steen et al (2011) build on Sanders and Stappers seminal paper and analyse benefits of co-design. They define **co-design** as “**creative cooperation during design processes**” and oppose it to **co-creation** “which also refers to creative cooperation **during service delivery and usage**, for example, to interactions between customers and service provider at service touch points.”

This definition distinguishes co-design and co-creation from a process perspective: co-design comes before the service delivery and usage. They separate the **design phase** and the **operation phase**. For a new service, this definition is satisfyingly distinguishing between both constructs. But for a re-design of an existing service, such as in our energy use case, this definition is more problematic. The users have already an interaction with the service (post-occupancy of the building) and the separation between "demand side" and "supply side" as formulated by Steen et al (2011) is not clear. With a **feedback loop** from operation phase to design phase, there will be a re-design of the service with stakeholders, meaning a co-re-design.

The co-created value or benefit

As expressed earlier, the notion of value co-creation is seen in this thesis as the outcome of the co-design process. The notion of value is also polysemic and in this thesis, **the co-created value can be understood as the benefits of the co-design process**. Steen et al (2011) propose, as in Table 3, to separate benefits of co-design in three categories: (1) • Benefits for the service design project itself (2) Benefits for the service's customers or users (3) Benefits for the organization(s) involved. They have reviewed the different potential benefits of co-design, based on a large literature review.

	Benefits for the service design project	**Benefits for the service's customers or users**	**Benefits for the organization(s)**
Improving idea generation	• Better ideas • Better knowledge about customers' or users' needs • Better idea generation		• Improved creativity • Improved focus on customers or users • Better cooperation between different people or organizations, and across disciplines
Improving the service	• Higher quality of service definition • More successful innovations	• Better fit between service and customers' or users' needs, and better service experience • Higher quality of service • More differentiated service	
Improving project management	• Better decision making • Lower development costs • Reduced development time or time-to market • Continuous improvements		
Improving longer-term effects		• Higher satisfaction of customers or users • Higher loyalty of customers or users • Educating users	• More successful innovations, e.g. rapid Diffusion • Improved innovation practices, processes and capabilities • More support and enthusiasm for innovation and change • Better relations between service provider and customers • Better public relations

Table 3. Benefits of co-design, adapted from Steen et al (2011).

In this thesis, "co-creation of value" means co-creation of a benefit for the different stakeholders involved in the co-design process. The value is not only from a customer's perspective or a company's perspective, as often in marketing. It is larger and can benefit the society as a whole. This part is missing in Steen et al list of benefits (2011) and could be an additional dimension. As mentioned by Vargo & Lusch, the value is always co-created when the service is consumed, as the value is the resultant of the process (2004).

The term "**co-design**" has been chosen in this thesis for its specificity, associated with the design of a service with stakeholders. In fine, the goal of the service design process is to co-create value with the stakeholders. **The co-creation of value is seen in this thesis as the outcome of the co-design process.** It is also mentioned by Steel et al (2011):

> *"The entire process of developing and providing services is (or should be) oriented towards delivering* ***benefits*** *for customers and users."*

1.3.3 How to define « energy conservation »?

To define **energy conservation**, one must begin to define **energy**. What is energy? Energy is defined by the Webster online dictionary as:

> *"a fundamental entity of nature that is transferred between parts of a* ***system*** *in the production of physical* ***change within the system*** *and usually regarded as the capacity for doing work" a second definition is proposed: "usable power (such as heat or electricity); also: the resources for producing such power."*[4]

One sees in these two definitions that the term "energy" can be understood differently. Patterson proposes a category and separation between "primary energy," "consumer energy," and "end use energy" such as in the Figure 9, which gives examples of the transformation process of energy from a natural resource to an end use (1996).

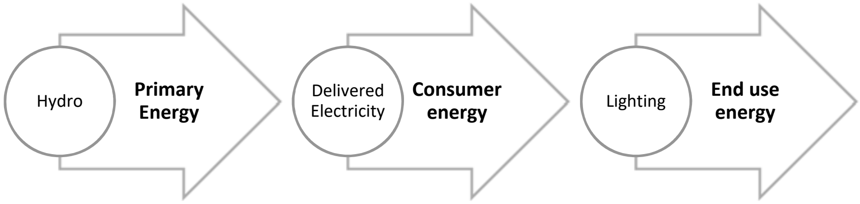

Figure 9. Different types of energy, adapted from Patterson (1996).

In this thesis, the term "**energy**" is used as the "end use energy" to provide an energy service such as lighting. The focus is on the service provision from a marketing and service science perspective.

What is energy efficiency? Patterson stated that not enough attention was dedicated to defining the terms and the indicators to operationalise it. In addition, he reports on the methodological issues when attempting to operationalise it.

"Energy efficiency is a generic term, and there is ***no one unequivocal quantitative measure*** *of 'energy efficiency.' Instead, one must rely on a series of indicators to quantify changes in energy efficiency. In general, energy efficiency refers to using less energy to produce the same amount of* ***services*** *or useful output." (*Patterson, 1996, p. 1).

[4] https://www.merriam-webster.com/dictionary/energy

The definition is illustrated in Figure 10 below. For Patterson, how to define "**energy input**" and "**useful output**" generates serious methodological considerations, often ignored in the literature. He categorises the type of indicators in four categories: (1) Thermodynamic, (2) Physical-Thermodynamic, (3) Economic-Thermodynamic, and (4) Economic. In the second category, there is an attempt to measure the "**service delivery of the process,**" Enthalpic efficiency only measures the "useful output;" the rest is wasted. Enthalpic efficiency is often called "first-law efficiency" referring to the first law of thermodynamics: *"in any conversion process, energy cannot be created or destroyed" (*Patterson, 1996, p. 2). He also mentions that the first-law efficiency does not consider the quality of energy, which he considers a serious methodological problem. He proposes his own operationalisation method.

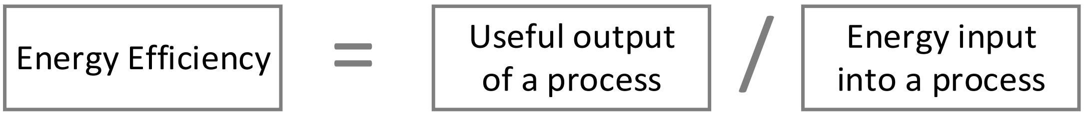

Figure 10. What is energy efficiency?, Adapted from Patterson et al, (1996).

In our understanding, "**energy input**" (primary energy, consumer energy) can be considered as the "production side" and "**useful output**" can be considered the "consumption side" ("end use energy"). It follows a transformation process from production to consumption. **Energy conservation** is considered in this thesis the action to reduce "energy input" for the provision of the "useful output." This thesis concentrates on the "useful output," the consumption side, the "**service delivery of the process.**" The idea is to better define what does "**useful output**" or "**service delivery**" mean, from a service science perspective and propose an innovative way to operationalize the "useful output." New methods need to be developed to quantify the "**useful output**" not only in economic terms but also on social terms. Marketeers and sociologists are specialists in this field.

The complex notion of "service"

There has been a shift in marketing with the seminal paper from Vargo and Lusch: "Evolving to a new dominant logic for marketing" (2004). They define a service as: *"the application of specialized competences (knowledge and skills) through deeds, processes, and performances for the benefit of another entity or the entity itself."* (Vargo & Lusch, 2004, p. 3). In the building case, engineers and architects use their specialized competences to develop artefacts (buildings, heating and ventilating systems, devices, materials…), which are the vehicles to bring the benefit (value) to the "occupants." This value is created when it is consumed. The value is always co-created in interaction with the system. *"Briefly, marketing has moved from a goods-dominant view, in which tangible output and discrete transactions were central, to a service-dominant view, in which intangibility, exchange processes, and relationships are central"* (Vargo & Lusch, 2004). From this Service Dominant Logic paradigm, the link between energy efficiency, service provision and co-creation of value is clearer.

More research on open innovation is needed in the service sector, as mentioned by Gassman, Enkel and Chesbrough (2010). Chesbrough focuses on open innovation in services in a paper where he makes the link between open innovation and co-creation: one step of the open innovation process is "service co-creation" (2011). He proposes the following model in Figure 11, with an interesting mention of "tacit knowledge" integration. The opening of the boundary of the company permits an integration of tacit knowledge from the surrounding environment, which includes "*customers, partners, complementors or other third parties.*"

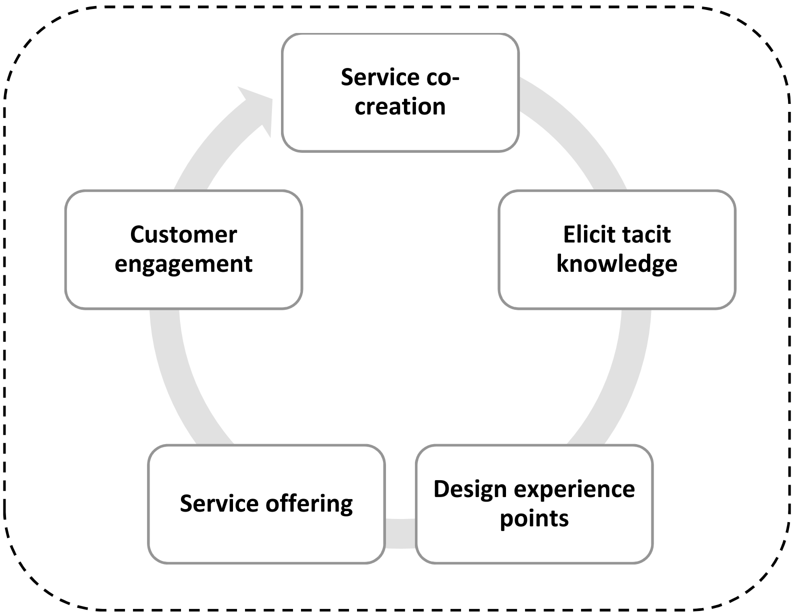

Figure 11. Co-creation process in the service sector, adapted from Chesbrough (2011).

It is clearly a **company centric perspective** with the "*surrounding environment*" represented outside the dashed lines. From this perspective, it seems that firms, in the building and energy sector, should engage the customers in activities to co-design an energy conservation intervention. However, it could also be understood differently, with a **customer centric perspective.** Heinonen proposes to become closer to customers: *"Instead of focusing on how customers can be engaged in co-creating with the firm, service providers should rather focus on becoming involved in the customers' lives."* (Heinonen et al., 2010 cited by Grönroos & Voima, 2013). Instead of integrating the customers inside the R&D department of utilities, companies should go outside the boundaries of the firm to learn from social practices, with ethnographic methods for instance.

With this perspective in mind, the role of the different actors in the system is changing. Users become co-designers, together with professional planners. Gassman et al. (2010) propose a changing role as well for the universities "*from ivory towers to knowledge brokers*" (p. 4), which goes in the same direction as Sanders and Stappers: the researcher is becoming a facilitator in the open innovation process (2008).

The concept of "energy services"

A recent research from Michael James Fell has been conducted on defining the concept (2017). He emphases the growing importance of **demand side management**, thus an interest in better defining "**energy services**". He analyzed 185 articles from two different journals containing the term "energy service*". This concept is mentioned in only 0.5% of the articles on the "Energy" thematic he analyzed. From these 185 articles, only 10% proposed a definition of energy services and 50% give examples of energy services (173 examples in total). Fell enlarged the literature review with "grey literature" and found 12 additional definitions. He found **inconsistencies** in the different definitions proposed and developed his own definition from a content analysis of the selected papers: ***"Energy services are those functions performed using energy which are means to obtain or facilitate desired end services or states."*** Figure 12 below illustrates this definition:

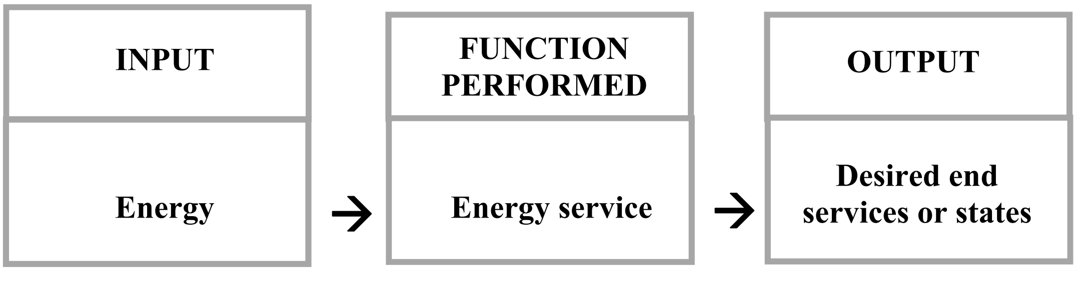

Figure 12. What is an energy service?, adapted from Fell (2017).

He differentiates the “**function**” and the “**end states**” which is not often the case in the different papers he reviewed: *“it is necessary to determine where energy services end, and the end services begin.”* […] He proposes examples: “The **energy service** ‘lighting’ is done for the purpose of being able to see at night (**end service**)”. (Fell, 2017, p.8).

To frame his research and analyze a “manageable” amount of literature, Fell has analyzed papers from two different journals, namely: “*Energy Policy*” and the recent journal “*Energy Research and Social Science*”. These journals are not focused on the “service” part of the concept “energy service” but on the “energy” part. In this thesis, we stand that the marketing discipline can contribute in defining “energy service” with a different and complementary perspective. Specifically, the Service Science could help define in general what is a service. This research is anchored in the **Service Dominant Logic** (SDL) paradigm, proposed by Vargo and Lusch in 2004. SDL is positioned at the cross roads of Marketing and Service Science disciplines. SDL considers that all economies are service economies and the service is what creates value for the residents. The watt, for instance, does not create value for the residents; they are only a product, a “vehicle” that brings the value of the service to the residents. The value (benefit) is always co-created when the service is consumed. When watts are lost during the transport, they do not create any value.

In the energy sector and from an engineering perspective, the consumers are often, for the moment, at the end of the value chain as consumers of the energy service. What if they are placed at the beginning of the value chain, as value co-creators, when they co-design energy services with key stakeholders? What would be the impact on energy performance of low consumption buildings? In the engineering discipline, the focus is often on the production part, on the input of the energy service provision, on the artefacts, a specific technology for instance.

In the marketing discipline, the focus is on the output, on the demand side, on the service provision in an SDL paradigm. A heating system for instance is not what creates value for the residents, what creates value is the energy service the heating system provides: “heating”, the end state is to feel warm and comfortable at home. **This theoretical framework of value co-creation within SLD is used at a meta level to decentralize the attention from product to services in a sector where technology is predominant.**

1.3.4 How to define « social marketing »?

First, the term "**social**" must be defined: "*Social: of or relating to human society, the interaction of the individual and the group, or the* **welfare** *of human beings as members of society.*"[5] In the scientific literature, Kotler and Zaltman coined the term social marketing in 1971 already:

> "*Social marketing is the design, implementation, and control of programs calculated to influence the acceptability of social ideas and involving considerations of product planning, pricing, communication, distribution, and marketing research.*"

From this first definition, a "social idea" is an idea related to the **welfare of human beings**. Kotler and Zaltman describe social marketing as a process which can be used to design a program, what we have called an intervention. In this paper, they propose an adaptation of the 4P's with a social dimension. After almost 50 years, this article still contains important insights, for instance on the pollution thematic which did not propose a clear "product" to buy, a clear call for action. With the multiplication of **uncoordinated actors**, it provoked an "interest overkill" (already mentioned in 1971). In the case of EE, it is of particular interest not to be focused merely on "monetary" costs but also "on opportunity costs," and "psychic costs," not often integrated in energy efficiency programs. *"The authors believe that specific social causes could benefit from marketing thinking and planning"* (Kotler & Zaltman, 1971). Presented that way, **marketing becomes a tool; it is not positive or negative**. The impact of the tool on society is positive or negative. Today, marketing is often used in a pejorative way among the population and has a manipulation connotation. The authors had already warned social marketers against this phenomenon in this paper in 1971. Marketing can also be used for a positive social implication.

In 2000, a psychologist, McKenzie-Mohr, frustrated to see that professional environmental planners did not use research knowledge on social marketing extensively, proposed a simple process to develop a social marketing intervention. He named it "**Community-based Social Marketing**". The process consists of four steps to follow to develop an intervention: (1) Uncovering Barriers and Selecting Behaviors, (2) Designing Strategies, (3) Piloting, and (4) Evaluation. This common process in marketing has been illustrated with different social

[5] https://www.merriam-webster.com/dictionary/social

marketing examples in his paper. The **change agent** is still a professional planner, but this planner is encouraged to research insight upfront and to test his plan in situ in pilots. This constitutes the **social marketing intervention**. The interest in this process is also to merge a marketing plan and an **energy conservation plan** to be able to better target the intervention to the audience. This is also the perspective of the research team when developing an intervention to increase energy efficiency in low consumption buildings.

1.3.5 The crossroad of the different conceptual frameworks

This thesis is at the nexus of production and consumption of energy services in low consumption buildings, requiring pluridisciplinary research: (1) to better understand the socio-technical system (Geels, 2004), and (2) to act upon it with an energy conservation intervention. In this part, the links between the different disciplines and conceptual frameworks will be proposed. In practice, engineers and architects are often focused on the **production side** and marketers, sociologists and psychologists are focused on the **consumption side**. These two different focuses show a clear separation between production and consumption, with different actors involved at each stage of the process, as it can be seen in the Figure 13 proposed by Geels (2004).

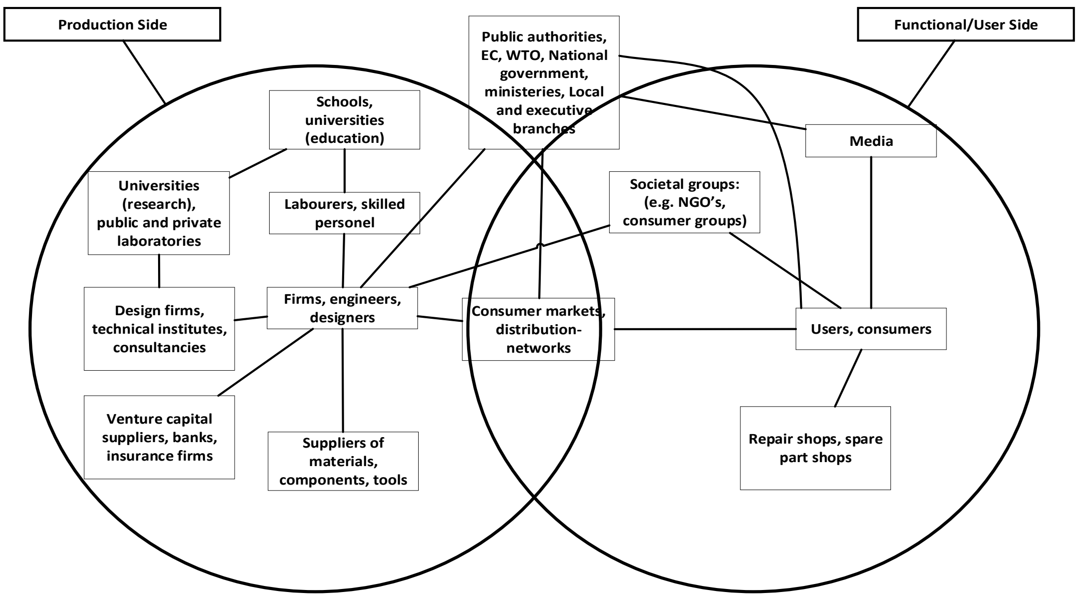

Figure 13. Social groups in the building sector, adapted from Geels (2004).

The service, by definition, is produced and consumed simultaneously (Vargo & Lusch, 2004), meaning that the boundary between production and consumption is not as clear as in Figure 13 and it is not obvious to separate "Production side" and "Functional/user side" as proposed by Geels in his model, with "Consumer markets, distribution-network" at the intersection (2004). As a result, it is not obvious to separate actors which participate in the "Production side" such as architects and engineers, and actors which participate in the "Functional/user side," such as "occupants," "users," and "consumers" (different terminology is used in different disciplines). With a co-design process, stakeholders traditionally considered in the "demand side", co-develop products, services and interventions, together with actors traditionally in the "production side".

The notion of "prosumers" complicates the modelization, as the consumer of energy can be the producer of his own energy: where to place the "prosumer" in this model? The model is always a simplification of a complex reality, but in this case, even the circles separating production and consumption should be reviewed in a service science perspective. As proposed by Vargo and Lusch, consumers are always co-creators of value when they consume the service; all economies are services economies (2004). What does this mean for energy services and for energy conservation? If an intervention is designed to **change the socio-technical system**, and if the consumer is always a co-creator of value, the social performance of the service depends on the ability of the socio-technical system to deliver the value. The proposition of the researcher is to **integrate the consumer in the value chain as a co-designer.** If the consumer is not satisfied with the value created in the system, he has the ability to become a prosumer and produce his own energy. He becomes a "lead user" as mentioned by von Hippel, developing a solution to answer his own needs because the solution provided by the market does not fully satisfy him (2005).

Companies such as utility companies and construction companies have the choice to integrate them or not. Consumers also have the option of modifying the socio-technical system to meet their own needs. Studying their consumption practices of everyday life and integrating them in the co-design of an energy conservation intervention would go in the direction proposed by OI. This is the proposition the research team will test in this thesis.

How does one integrate the different actors mentioned by Geels (2004)? LL proposes a typology of stakeholders using the quadruple helix model: (1) academics, (2) public authorities, (3) private companies and (4) citizens. Bottom up innovation is the central approach. In LLs, actors are not separated by "Production side" and "Functional/user side" as proposed by Geels (2004) but are joint together in an eco-system of actors contributing with their interaction to the co-design of the intervention. LLs are considered innovation intermediaries orchestrating the OI process. They play the role of catalysts as well. Steels et al have also proposed an important contribution to the benefits of co-design:

> *"The process of co-design also yielded some unexpected benefits. First, the research results changed the implicit assumptions of the researchers. So, in addition to gaining new ideas or views, co-design can also help to change existing ideas or views*." (2011, p.55).

Such assumptions are embedded in the different parts of the Socio-Technical system: norms, actors, artefacts (Geels, 2004). National architectural norms for instance are based on assumptions on usages. Artefacts such as the automate regulating the ventilation system are based on assumptions. Researchers have also made assumptions on the level of power and interest of the different actors that may differ from the reality. These assumptions, proposed during the design phase (pre-occupancy phase), may not be accurate and co-design with stakeholders could change these assumptions with a feedback loop from the operation phase to the design phase. Thus, the interest of agile methods integration in LLs.

1.4 Epistemology and methodology: constructivism, multi-methods

This section will present the epistemological paradigm of the research and the overall methodology of the thesis. The methodology of each scientific article will be presented in the related chapters and not in this overall introduction on the different methods used in the thesis.

1.4.1 Epistemological paradigm: science of artificial and constructivism

An important step in this doctoral thesis is to define in which scientific paradigm it is anchored. A scientific paradigm is: "*A beliefs system about what is a science, what it does study and how*."[6] (Gavard-Perret, M. L. et al., 2008, p. 13). Different paradigms exist, often linked to different disciplines. As this research is pluridisciplinary, it is of particular importance to understand the different paradigms of the researchers involved in the project. The science of the artificial paradigm as defined by Simon (1996, cited by Gavard-Perret, M. L. et al., 2008, p. 18) distinguished the artificial from the natural by four indicia:

> *(1) Artificial things are synthesized […] by human beings. (2) Artificial things may imitate appearances in natural things while lacking, in one or many respects, the reality of the latter. (3) Artificial things can be characterized in terms of* ***functions****, goals, adaptation. (4) Artificial things are often discussed, particularly* ***when they are being designed****, in terms of imperatives as well as descriptives.*

The studied low consumption buildings and the energy services provided to the occupants can be seen as artefacts synthesized by architects and engineers. They pursue the goal of satisfying the needs of the occupants with the efficient consumption of resources, providing functions: lighting, heating, informing... The design phase is of particular interest in this research because the building company would like to better understand the impact of co-design with stakeholders for future low consumption buildings. In the co-designed energy conservation plan, actions can be directed toward changing the three elements of the system: actors, rules, technical artefacts. Different type of rules such as the construction standards SIA 380/1 and SIA 380/4 provide an imperative framework. In this respect, the thesis is anchored in the science of artificial paradigm.

[6] Un paradigme scientifique : « Un système de croyances relatives à ce qu'est une science, à ce qu'elle étudie et à la manière dont elle l'étudie.

It is also important to define in which epistemological paradigm the thesis is situated. Epistemology is defined by Piaget as "*the study of the constitution of valid knowledge*"[7] (1967, in Gavard-Perret, M. L. et al., 2008). By valid knowledge, two points of view can be defined: (1) **epistemic value**: does this research have a value for the development of the general knowledge? (2) **pragmatic value**: does this research have a value for the managerial practice? (Gavard-Perret, et al., p. 7). As it is often the case in marketing, this applied research intends to develop both types of value: (1) **epistemic value**: better understand and measure the impact of the co-design process in a LL and the impact on energy performance (2) **pragmatic value**: propose an innovation process resulting in recommendations that contribute to increased energy efficiency in the studied low consumption buildings.

Two main epistemological paradigms are dominant today: **positivism and constructivism**. In the positivism epistemological paradigm, the researcher adopts a neutral posture and observes in order not to influence the studied phenomenon. For instance, researchers in econometrics participating in the UserGap project adopting this epistemological paradigm could say "I do not want to increase energy efficiency; I want to measure, with the smart meters installed in the neighborhood and the data from the survey, the effect of such co-design process on the energy consumption of the occupants." They would elaborate the hypothesis and test it empirically with econometric models. In the research for the Swiss Federal Office of Energy, the goal is to find a process to increase the energy efficiency in low consumption buildings. There is a strong managerial implication, this cannot be considered as a neutral position.

As a PhD candidate and a researcher, my epistemological paradigm is **constructivism**: from my point of view, the observer cannot be separated from the observed phenomenon; he constructs his understanding of a reality and of the phenomenon, with his own subjectivity. Numerous stakeholders are involved in the research project and the researcher adopts the role of facilitator in the innovation ecosystem (Sanders & Stappers, 2008). It is not a neutral position but a changing role of the researcher. The building system is interpreted from the different subjective perspectives of the stakeholders. As researchers, we intend to collect subjective perceptions from these actors.

[7] Epistémologie : « L'étude de la constitution des connaissances valables. »

How are the two paradigms, positivism and constructivism, conciliated in the same research? We propose to separate clearly the different roles: the engineers, statisticians and specialists in econometry with a **positivism** paradigm will do a literature review; they will propose hypotheses on the determinants of energy consumption and test the hypothesis before the interventions in the buildings. They will have access to historical data on energy consumption (water, electricity, and temperature) and data from surveys. From their first hypothesis testing, and from a **constructivism** paradigm, the author will pilot different energy conservation interventions, co-designed with the different stakeholders. The research team will try to gather knowledge from surveys, qualitative interviews, workshops and crowdsourcing techniques. Then the engineers, statisticians and specialists in econometry will again measure the impact of the intervention on energy performance. The richness of this pluri-disciplinary team permits a combination of quantitative and qualitative methods to measure the impact of the intervention.

1.4.2 Methodology: sequential multi-methods and level of analysis

Low consumption buildings will be used as Living Laboratories where in situ interventions will be conducted using **sequential multi-methods**. Different stakeholders will be invited to participate: (1) researchers in social sciences will have a role of facilitators and will conduct and moderate the experiment, (2) researchers in econometrics will measure the energy performance before and after the different interventions, (3) engineers will monitor the buildings of the neighborhood and separate the influence of the buildings and the influence of the occupants on the overall energy efficiency of the buildings, (4) public authorities will set the legal and policy framework, (5) Building companies will give access to the buildings and to the consumption data and they will use the results for the design of future low consumption buildings, (6) Occupants will participate in the different phases of the applied research: survey, qualitative interviews and workshops and (6) Minergie association will use the results of the research to evolve the labelling process and communicate the results of this research.

In this thesis, **different levels of analysis** are used. In the first paper, the level of analysis is the LL. The objective is to define what its characteristics and success factors are. In the second paper, the perception of inhabitants regarding energy services is analysed, the unit of analysis is on the practices. In the third article, the research teams ask energy consumers to give ideas for developing energy services; the unit of analysis is on the practice. In the fourth article, the research team tested the LL method and the integration of multiple stakeholders in the co-design of a Building Energy Management System (BEMS). The unit of analysis is the ecosystem of actors in the building and the relationships between the actors. In the last paper, a conceptual framework is proposed to better understand the Energy Performance Gap. The level of analysis is the practice as the author tries to understand the "social performance" generated by the energy service. This is not a case of our colleagues working at different levels, as illustrated in Figure 14 below. Engineers mainly work at the scale of the building as it is expensive to analyse the technical performance of buildings in details in an entire neighbourhood. Studying only one part of the building (one room, one apartment) does not give the full picture of the building consumption and the common surfaces. Our colleagues, the statisticians and economists, mainly use quantitative data analysis, which is intended for a big data set, such as the analysis of the entire neighbourhood. Reconciling the different units of analysis in pluridisciplinary projects such as UserGap is complicated but gives different perspectives of the same construct: the "energy performance gap."

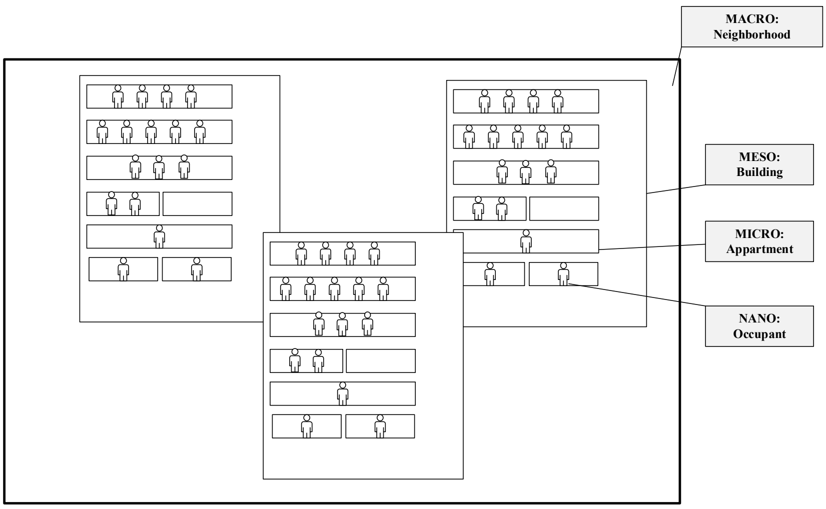

Figure 14. Different levels of analysis in the neighbourhood.

1.4.3 Structure of the thesis

This thesis is structured in nine chapters; five of them are composed of scientific articles presented at international conferences (in Table 4 below), plus two vulgarization papers, framed by an introductive chapter and a conclusion. Two of the articles have been published in scientific journals. The progression of the thesis follows a theory building logic with an inductive approach (Saunders et al., 2016, p. 74): we construct the theory on an energy performance gap from the data collected in the previous studies (ELL pilot and UserGap). The different sub-questions are presented in Table 4, which concludes a new theory of the energy performance gap, integrating the insights of three main disciplines: (1) marketing, (2) engineering, (3) economics.

Article	Title of article	Research questions	Method
1	« How to keep a living lab alive? »	What defines a Living Lab concretely? What are the common characteristics of Living Labs? How to evaluate LLs?	Literature Review Case study
2	"Perceived Value of Energy Efficiency Technologies in a Sustainable Neighborhood: an Empirical Enquiry from the Energy Living Lab"	How are the energy services perceived by consumers in low consumption buildings?	Empirical inquiry Qualitative interviews
3	"Trust and technology: two dimensions to open and agile innovation applied to the consumer energy market"	What is the role of trust in a co-design process? How to establish and maintain relationships of trust among the stakeholders?	Comparative Multiple Case Study
4	"Energy Management in a Public Building: A Case Study Co-Designing the Building Energy Management System"	How are different stakeholders integrated in the co-design of an energy conservation intervention (BEMS)	Case Study Qualitative interviews
5	"A Conceptual Model Analysing Building-in-Use to Act on Energy Performance Gap"	Is there a "social performance gap" in energy services? How is this measured?	Conceptual Theory Building

Table 4. Structure of the thesis, research questions, methods.

Article 1: This chapter is an introduction into the world of LLs. In order to consider a potential contribution of LLs to energy performance, the LL phenomenon has to be described. Key characteristics and business models are analyzed in this chapter. The ELL pilot project is used as a case study to illustrate how the phenomenon could be transferred in the energy sector. This article has been written during the launch of the ELL in 2014. It has been presented at ENoLL annual conference. The Lab is envisaged as a particular type of **innovation intermediary** supporting the co-design of products and services. This article had a strong managerial contribution as it contributed to change the perceptions of what is a LL and how to evaluate it over the time and in different contexts.

The following articles refer to different steps of the **Living Lab Integrative Process** the author intends to test in this thesis: (1) Selecting a practice, (2) Integrating Stakeholders, (3) Uncovering the barriers, (4) Co-designing the plan, (5) Piloting an intervention, (6) Evaluating performance. The entire process is illustrated in the Figure 15:

Figure 15. Living Lab Integrative Process.

Article 2: LLs are strongly linked to the context in which they operate. The first step of the proposed "**Living Lab Integrative Process"** is to select one or more practice(s), and to understand its **context of appearance.** The second article is **exploratory** and focus on heating, lighting, moving practices in a sustainable neighborhood composed of low consumption buildings. It is based on a satisfaction survey proposed by the constructor three years after the construction. It explores the different **barriers toward energy conservation**. This survey is supported by qualitative semi-directive interviews with the inhabitants to get the insight on the latent barriers, not explicitly mentioned in the survey. Before engaging the key stakeholders in a co-design process and influencing their perceptions on energy, pre-intervention data are gathered. From our point of view, understanding the context before acting with a quasi-experiment is a fundamental success factor in LLs.

Article 3: This article focuses on **trust and technologies** as important factors to co-design interventions. LLs do not work on their own but are part of a European movement: The European Network of Living Labs (ENoLL). Other labs are working in the energy field such as Lorraine Fab Living Lab. This article is based on two case studies run independently. Both the co-design process and the outcome are compared in this analytical article. The contexts in which the two LLs operate are different (Switzerland and France). Key success factors of co-design in LL emerge from this analytical comparative process.

Article 4: How to engage the key stakeholders? What is their respective level of power and interest? Are their influencing each other? The fourth article explores these questions in an intervention in a low consumption building. In 2017, the ELL begins to structure its process and document it in details to replicate and test it further. The engagement process is the core of this article, presented at IEEE ICE conference in Madeira in June 2017 where architects, managers and engineers converge to learn from each other and co-develop knowledge.

Article 5: This article builds **upon the data gathered** during this extensive period of **longitudinal study**, from the creation of the ELL in 2014 to its development and structuration until 2018. From the past learnings collected through the different projects, it seems that the core of the energy performance gap does not lie in the technical gap nor in the economic gap. An element is missing in the existing models of EPG: the "**social performance**". This theoretical article proposes a new construct: the "Social Performance Gap", influencing, together with the technical and the economic, the total EPG. In this article, methods are proposed to measure this social performance gap quantitatively through proxy variables. This inductive research contributed with a new theoretical model of EPG.

Article 6: This paper was published in a professional journal in the field of energy. It explains how the methods are set, in the specific sector of district heating systems. The main impact of this article is managerial. It illustrates part of the tools used in LLs in two case studies.

Article 7: The last paper of the thesis has also been published in a professional journal. It concentrates on the value of participatory methods. A checklist is proposed in order to replicate this method in other contexts and to test the process proposed in the thesis.

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Chapter 2

How to keep a living lab alive?

Before being able to determine what could be the contribution of LLs in the field of energy and particularly on the challenge of the energy performance gap, it is first necessary to define what a LL is. What are the criteria that make a phenomenon called LL? What are the characteristics for a LL to be sustainable over the time? These are the questions that will be addressed in this chapter, through the ELL case study. Indeed, when the ELL pilot project was set up in 2014, the aim was to better define conceptually and also in an operational way what the activities of this laboratory would be. The following article was presented at the annual conference of ENoLL in August 2014. Then a completed version was accepted in the INFO journal in January 2015[8]. This journal has dedicated a "special issue" on the theme of LLs. Our article was selected for its contribution, which allows a reflection on the business model of living labs with an example in energy. By 2014, the energy sector had few LLs initiatives. It has since grown significantly.

[8] Draft version before publication

How to keep a living lab alive?

Mastelic, J., Sahakian, M., Bonazzi, R., (2015), How to keep a living lab alive? *Journal INFO*, Vol. 17 Issue: 4, pp.12-25, January 2015, https://doi.org/10.1108/info-01-2015-0012[9]

Abstract

This paper explores how Living Labs might be evaluated, building on the current efforts of the European Network of Living Lab (ENoLL) to encourage new members, and complementing their existing criteria with elements from business model development strategies – specifically the Business Model Canvas (BMC) (Osterwalder & Pigneur, 2010). First, we explore how Living Labs have emerged, at the intersection of transition management, open innovation and collaborative consumption. We then suggest that the BMC could be a complementary tool in Living Lab evaluation. This tool helped to identified three important elements missing from current ENoLL evaluation criteria: identification of the cost structure, customer segments and the revenue stream. We use the case study of an Energy Living Lab created in Western Switzerland to reflect on the strengths and weaknesses of different evaluation criteria, then conclude with some ideas on how future research might contribute to further strengthening Living Lab evaluation process towards long-term 'sustainability'. This article will be of value for ENoLL to refine their evaluation criteria for the next "wave" of application. It could as well help living labs to reflect on how to keep a living lab alive.

Keywords: living lab; open innovation, evaluation criteria; business models, ENoLL

[9] Draft version before publication

2.1 Introduction

Researchers and practitioners have been preoccupied for some time with addressing complex problems at the nexus of society, economy and environment. Different forms of learning have been promoted, such as participative workshops towards visioning and backcasting, as well as different forms of production and consumption, including open innovation and collaborative consumption. In recent years, what are known as Living Labs have emerged, as spaces for innovative and participative research, development and activity deployment, using multi-disciplinary methods and approaches, and bringing people together in social contexts around a range of themes. Living Labs have attracted the attention of the business sector, researchers and teachers, as well as the public sector and communities. In Europe, a platform exists for promoting such sites of applied and action research: headquartered in Brussels, the European Network of Living Labs (ENoLL) is a non-profit organization founded in 2006, with support from the Finnish European Presidency. ENoLL defines a Living Lab as: "*a real-life test and experimentation environment where users and producers co-create innovations*" (ENoLL, 2014). Underlining the value of Living Labs in improving the research and development phase, through public-private partners and its focus on small-to-medium enterprises, the European Commission has also lent its support to further investigating the cross-border Living Lab networks in Europe. In 2009, the European Commission issued a report on the methodologies and achievements of Living Labs, further defining Living Labs as "*a user-driven open innovation ecosystem based on a business – citizens – government partnership which enables users to take an active part in the research, development and innovation process*" (EC 2009).

According to ENoLL, a Living Lab engages in four main activities: (1) Co-creation, (2) Exploration, (3) Experimentation and (4) Evaluation (ENoLL, 2014). One of the missions of ENoLL is to benchmark best practices among its members and to increase the number of participants in its network in a series of 'waves' or annual calls for membership. The 8th Wave membership application to join ENoLL ended on the 21st of May 2014; Living Labs that passed the evaluation criteria joined the existing network which grew to 370 Living Labs across the world. Numerous case studies exists on Living Lab methodologies and around a variety of thematic areas, mostly related to more 'sustainable' forms of production and consumption, in areas such as mobility (Rizzoli & al., 2014), smart cities (Coenen et al., 2014; Schaffer & al., 2011), ambient assisted living (Krieg-Brückner & al. 2010), or even vending machines

(Newman, Elliott, & Smith, 2008). Research has also focused on the various tools to co-create products and services with users in a Living Lab (Pallot & al., 2010), recognizing that a variety of methodologies and approaches are applied in Living Labs. Less attention has been paid to the evaluation criteria of a Living Lab and how such an evaluation contributes to the LL performance: what defines a Living Lab and how does such criteria ensure the sustainability of such an activity over the long term? Can the system of evaluation tell us something about why some Living Labs persist over time while others do not endure, despite passing the ENoLL evaluation phase? As Wu suggests (2012), better clarity on the purpose and mechanism of Living Labs as viable business models could lead to easier access to long-term financial support. In this paper, we address the question of evaluating Living Labs and propose to draw from the Business Model Canvas (BMC), a strategic management tool originally developed by Osterwalder and Pigneur (2010), to assess whether the existing evaluation criteria proposed by ENoLL could be augmented.

The first goal of this paper is to better understand what defines a Living Lab concretely? What are the common characteristics of Living Labs? With the evaluation criteria, ENoLL defines which organization can be considered as LLs and which cannot. It is key for ENoLL to get an academic view on this theme as the network has grown so quickly since 2006 and is actually working on its strategic development.

The second goal is to understand if the actual evaluation criteria are strong enough not only to assess if an organization is a LL or not but also to assess the sustainability of the LL. In launching the Energy Living Lab, a new effective member of ENoLL in 2014, a recommendation letter from another actual ENOLL member was mandatory. Three ENoLL LLs were contacted, one was clearly dead but always on the internet site from ENOLL and considered as a member, one was alive but passive, with no research activity linked to the network, and one was alive, but was not really focusing its activity on co-creation. It was clear for the authors that some of the members were not alive and active, information that has been confirmed by ENoLL. Through a more strategic assessment, Living Labs could better plan their activities and evaluate their processes, in order to continue their operations over the long term. By considering evaluations at the level of ENoLL, we hope that such strategic approaches could be shared across the landscape of Living Labs in Europe, to remain in activity over the long term.

In the section that follows, we briefly describe our methodology. We then follow with a description of how Living Labs emerged in Europe, from a historical perspective and in relation to different strands of research and practice. In the next section, we provide an overview of existing evaluation criteria aimed at selecting future members of the ENoLL network and place this in relation to the BMC. Finally, we apply the criteria to the case study of the Energy Living Lab, established in Chablais Region in Western Switzerland. We end with a discussion around our main findings and propose future research directions focused on evaluating Living Labs through the prism of business model development, understanding the role of LLs as innovation intermediaries.

2.2 Methodology

This paper includes a historical overview of how Living Labs have emerged in the case of Europe, using a literature review of existing secondary sources. We present different evaluation criteria based on existing literature. Secondary and primary data on ENoLL evaluation process and criteria have then been collected. The (BMC) Canvas has been used to allow a thematic classification of the different evaluation criteria and to highlight if there was a gap in the evaluation or if all the main components of a business model have been assessed. A lot of other models exist (Al-Debei & Avison, 2010). The BMC has been chosen because it is the most used, easily understood by non-specialists and give a visual overview to assess the key components of a business model. ENoLL has been satisfied by this pragmatic approach.

The case study on the Energy Living Lab established in Western Switzerland is based on an analysis of qualitative data collected from seven in depth interviews with stakeholders from November 2013 to January 2014 including public authorities from the Chablais region, three SME participating in the Living Lab, two managers of other existing living labs, ihome Lab Luzern and MobiLab Geneva and the director of EPFL in Wallis Region. A workshop with the stakeholders which took place in January 2014 has also been transcribed. Qualitative data collected during the workshop have been compared to the face-to-face qualitative interviews to see the similarities and divergences. Through this process, we are able to assess the different criteria proposed for evaluating Living Labs, including their strengths and weaknesses. To classify ENoLL effective members, this paper draws on previous research on typology of innovation intermediaries proposed by Lopez-Vega and Vanhaverbeke (2009). They have based their typology on 32 case studies, partly composed of Living Labs (f.i. IBBT in

Belgium). We have used the same methodology and distributed the different effective members among the four types of innovation intermediates, based on secondary data on Internet. In a table, we have analyzed the components of the business models of each effective member: value proposition, value chain, market segment, value network, competitive strategy and, revenue model. For each component, they have defined measurable variables that we have also used in this paper to categorize the different Living Labs with the same methodology.

2.3 Historical perspectives: the emergence of Living Labs

Pallot and his colleagues have already begun to map the domain landscape of Living Lab research (2010), presented at the first ENoLL summer school. The following section complement with a historical perspective of the different theoretical frameworks preceding Living Lab methodology.

Living Labs emerged in Europe and North America at the convergence of different forms of research and practices, including social learning, collaborative consumption, open innovation and participative methods, to name but a few. In this section, we will detail select strands leading to the increasing popularity of Living Labs today. The complexity of addressing issues at the nexus of societal, economic and environmental dimensions has led to interest in novel approaches, as achieving transitions to 'sustainability' as a normative goal have proven difficult. Two main issues can be raised here: how 'sustainability' is framed as a research and societal problem, and how efforts towards more 'sustainable' can engage with different stakeholders in participative forms of research, action and learning, questions that are at the heart of 'sustainability research' in social sciences today (Rau and Fahy, 2013).

In transition management studies, participative forms of back-casting emerged in recent years in relation to 'sustainability' (Kerkhof and Wieczorek 2005), which includes stakeholder involvement and dialogue, participation in the generation of desirable futures (visioning) and learning through involvement and interaction (Quist and Vergragt 2006). While back-casting was first proposed in the 1970s in relation to energy studies (Lovins 1977), participatory back-casting has gained in popularity since the early 1990s, with researchers in The Netherlands leading the way (Erkman 2004). Participative visioning and back-casting workshops have been found to stimulate an understanding of the cultural norms of consumption (Davies, Doyle et al. 2012), and have used various techniques such as role-playing to further stimulate innovative ideas towards future sustainable lifestyles (Guillen and Nicolau 2013). In the case of energy consumption and production, one important thematic area within 'sustainability' research, these approaches are relevant when it comes to understanding how people learn new technologies, such as smart meters and energy-efficient lighting, and project themselves into future scenarios, but become all the more relevant when we consider households as having the potential to become producers of renewable energy in an increasingly liberalized energy market or 'prosumers' (Darby 2012). Household members are not only passive recipients of technologies and energies, but also active participants in a changing energy provisioning landscape. Living Labs in Europe today also focus on such participative methods, drawing on socio-technical transition theories. The main assumption here is that system innovations occur at the intersection of technologies along with human agency and institutional contexts (Kemp and van Lente in Cohen *et al.* 2013).

The notion of open innovation further expands this idea, which originated in the context of business enterprises. Open innovation is a process by which valuable ideas emerge and are confronted to the market by actors both 'inside' or 'outside' the company (Chesbrough 2003). According to Chesbrough, open innovation consists in using external creative resource to integrate them into the innovation process, which goes beyond the boundaries of the firm. Similarly, Köpcke (2008) views the 'external' collaboration is a process by which 'customer needs' can be better understood, resulting in better public adoption and acceptance of certain 'innovations' within a specific context, particularly as the average rate of innovation can be quite high. The author identifies four factors to take into consideration in an open innovation project: (1) open innovation requires a win-win situation; (2) open innovation is built on trust; (3) open innovation provides opportunities for development, cooperation and collaboration with external partners and competitors; (4) open innovation is more specifically focused on consumers and customers.

In the 1980s and 1990s were a period, in Europe and North America, where consumers were seen not solely as seekers of physical and psychological satisfaction, nor mere dupes of producers and their marketers, but rather 'empowered' personality seekers (Sahakian 2014). It follows that more attention was given to how people come up with new trends and the possible market opportunities associated with such trend-setters. Building on the earlier work of Everett M. Rogers on the *Diffusion of Innovations* (1995, originally published in 1962), Malcolm

Gladwell (1997) describes the ‘innovator’ as the small group of people who originally generate new ideas and ways of doing, while the “early adopters” are the immediate followers of this trend, followed by the “early and late majority”, or the millions who buy into the trend or join once products and services are more readily available. Other authors such as von Hippel (2005) deepen the notion of users, including the concept of ”lead user”, constituting a group of users who have already explored innovative ways to respond to their needs.

Since the early 2000s, there has been a shift in how the process of value creation is understood: final consumers are involving in collaborative forms of consumption, not solely an elite set of consumers, but everyday people (Botsman and Rogers 2010). For example, the customization of sneakers by Nike and through NikeiD web platform illustrates this phenomenon. Here, customer involvement is based on customization of a mass product at a later stage in its development.

Much of this trend towards collaborative forms of consumption and production stems from the possibility of sharing information over the Internet, including via social media tools. In 2006, for example, Wired Magazine coined the term ‘crowdsourcing’ as opposed to ‘outsourcing’, distinguishing both the type of agents involved and the process (Howe 2006). In the outsourcing process as in the crowdsourcing one, the externalized object is a work usually performed by an employee, however in a crowdsourcing process, the agents to whom the task is subcontracted are not previously identified. Crowdsourcing is a practical outcome of the Internet tools. It confers a quick and easy way to appeal to a large community to gather ideas to deal with a problem (Mendonca and Sutton, 2008). In recent years, specialized commercial platforms in providing creative resources from an ‘external’ group have emerged, such as Atizo.com in Switzerland.

What can be noted in this brief historical introduction to the growing popularity of Living labs today is that the concept of a Living Lab stems from different interest areas, including researchers focused on ‘sustainability’ issues, as well as the private sector that sees such platforms as an opportunity for new forms of business development, and finally a public sector that also sees the value in such participative methods. It is interesting to note, however, that best practices from the world of business development may not have yet been applied to understanding how Living Labs can be created and persist over time, as a viable enterprise – whether funded through private, public of mixed sources. One attempt towards this goal has been the ‘harmonization cube’, (Mulder, Velthausz and Kriens, 2008; Genoud *et al.* 2009). As Mulder *et al.* (2008) discuss, there is a need to continue sharing information on the process of creating and maintaining Living Labs, which would ensure a sustainable network on open innovation. While the mapping towards performance criteria used by the ENoLL community to evaluate the Living Lab applicants is a good starting place, current versions of this criterion, used in the 8th wave, have evolved since those earlier papers. What follows is an evaluation of current criteria used in the ENoLL process for approving new members.

2.4 Analysis of Living Lab evaluation criteria

In this section, we will briefly describe the different memberships proposed by the European Network of Living Labs (ENoLL) and introduce the current evaluation process including the criteria used in the evaluation of the 8th wave of Living Lab applications. We then present the BMC to assess what aspects of the ENoLL evaluation criteria might be further enhanced through business model development tools.

ENoLL opens each year with a new ‘wave’ or call for participation in their network, which gives the opportunity for Living Labs who pass their qualification to be granted the use of the ENoLL Label as proof of certification. Such entities are then given a membership certificate and are officially recognized as being an **adherent member** of ENoLL during the annual conference and it is as well published on the OpenLivingLabs website. Adherent members do not pay any annual fee but only administrative costs of 500 euros. They do have access to a part of ENoLL service but not to the full portfolio of services. If an adherent member wants to become an **effective member**, a written application needs to be sent to ENoLL and after the approval of the general assembly, an annual fee of 5’000 euros is due. Effective members get access to the full range of ENoLL services and have the right to vote during the general assembly. They can as well submit candidatures for the ENoLL elected bodies. A third membership category is **associate member**, an organization which is not a Living Lab but that support the Living Lab association in its activities and orientation. The annual membership fee is due, but they do not have voting rights at the general assembly. They can submit candidatures for the ENoLL elected bodies and get voting rights if elected (ENoLL, 2014).

In 2014, only 19 Living Labs were effective members and 3 were associate members out of 370 total members. The ENoLL network has grown really quickly since 2006 and the number of adherent members has grown but the number of effective members has not followed the same trend. It would be interesting to understand who are these 19 effective members that participate actively in the network, from an academic point of view but also to help ENoLL expend the network qualitatively.

As described on their web pages and after an interview with Ana Garcia, Project and Network Manager at ENoLL (December the 18th 2014), the process for selecting new members is as follows: each Living Lab that wants to be adherent member of the European Network of Living Labs must complete an application form. This application form is then transmitted to three experts from different EU nations that conduct the evaluation. They are charged with reviewing applications that pass the eligibility test. Evaluators cannot consider projects from their own country, to remove certain biases, and each proposal is scored according to selection criteria. The evaluation criteria are grouped into thematic and have the same rating, there is no weighting applied. When the three experts have finished their evaluation, they discuss together about the discrepancies. An average of the three evaluations is then applied. Each of the thematic must be rated above the average (minimum rating of 2.5 over 4). The experts' evaluation is then transmitted to a committee that does a cross-evaluation to see if group of experts have rated above or under the other and to ensure the consistency of scoring. The criteria currently being proposed in the 8th wave are presented in Table 5.

	Criteria
1.	Evidence of co-created values from research, development and innovation
2.	Values/services offered/provided to LL actors
3.	Measures to involve users
4.	Reality usage contexts, where the LL runs its operations
5.	User-centricity within the entire service process
6.	Full product lifecycle support – capability and maturity
7.	LL covers several entities within value- chain(s)
8.	Quality of user-driven innovation methods and tools
9.	Availability of required technology and/ or test-beds
10.	Evidence of expertise gained for the LL operations
11.	Commitment to open processes
12.	IPR principles supporting capability and openness
13.	Openness towards new partners and investors
14.	Business-citizens-government partnership: strength and maturity
15.	Organization of LL governance, management and operations
16.	Business model for LL sustainability
17.	Interest and capacity to be active in EU innovation systems
18.	International networking experience
19.	Channels (e.g. web) supporting public visibility and interaction
20.	People/positions dedicated to LL management and operations

Table 5. ENoLL criteria for Living Lab proposal evaluation, adapted from ENoLL.

In this article, we propose to use the Business Model Canvas (BMC) to group the different evaluation criteria into categories and to understand if the whole business model of the Living Lab is assessed in the evaluation phase. Developed by Osterwalder & Pigneur (2010), the Business Model Canvas (BMC) is a model used for strategic business development, for both new and existing businesses. Based on the ontology of various business models (Osterwalder 2004), the BMC is useful for describing, analyzing and designing business models. BMC offers a visual diagram that includes the following nine elements, detailed in annex 1: key partners, key activities, key resources, value proposition, customer relationships, channels, customer segments, cost structure, revenue streams.

As can be seen in Figure 16, the 20 ENoLL evaluation criteria presented in Table 5 have been distributed in each section of the business model canvas. What can be seen at a glance is that there is no evaluation criterion covering (1) Cost structure, or (2) Customers segments. The criterion dedicated to (3) Revenue stream is also quite vague, represented solely by the request for a “Business model for LL sustainability”.

What follows is an analysis of how these three sections could be further augmented for ENoLL evaluation processes, based on the case study example of the Energy Living Lab based at the University of Applied Science Western Switzerland.

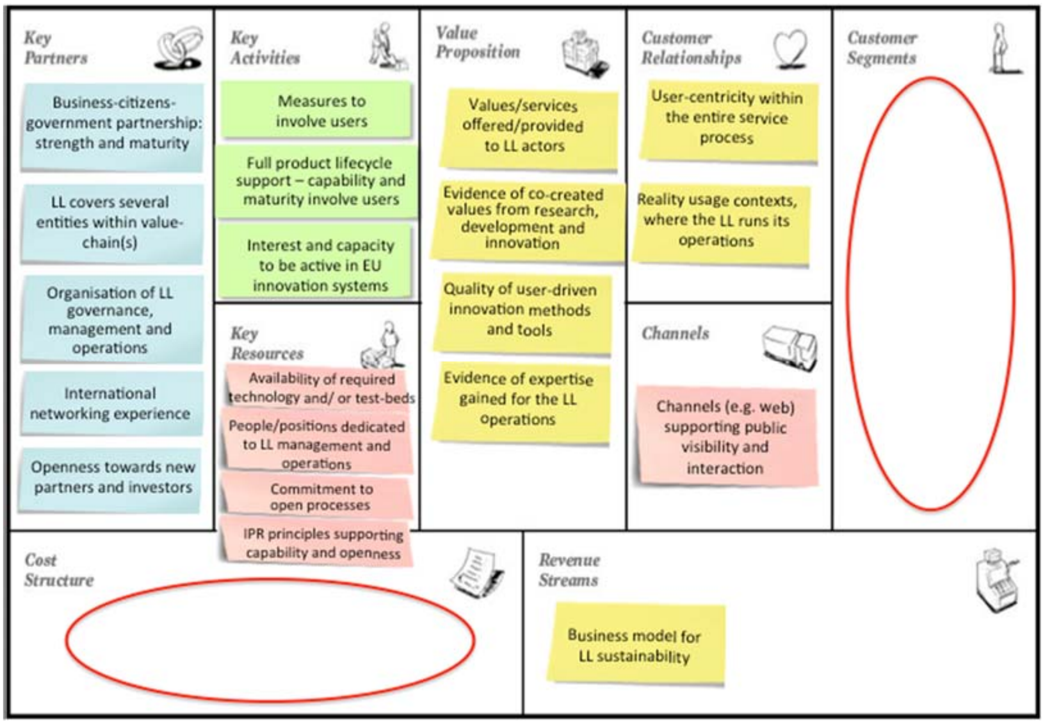

Figure 16. ENoLL criteria applied to the Business Model Canvas, adapted from Osterwalder & Pigneur, 2010.

2.5 Applying the evaluation criteria: the case of Western Switzerland Energy Living Lab

As presented below, three main elements are missing from the current ENoLL evaluation process for Living Labs in Europe: (1) cost structure, (2) customers segment, (3) revenue stream. We firstly introduce the Energy Living Lab created in 2014 in Western Switzerland. Then each missing element will be discussed, and illustrated with the case study of the Energy Living Lab. We also introduce some other ideas for evaluation criteria that could be further researched and discussed.

The Energy Living Lab, effective member of ENoLL as of September 2014, is an open innovation ecosystem dedicated to energy efficiency and the development of renewable energy in Western Switzerland. It is composed of the University of Applied Science Western

Switzerland, host of the Living Lab, Chablais Agglo representing the public authorities of this French-speaking region, private companies in the field of energy, together with an association of users.

The goal of the Living Lab is to empower the users of energy (citizen of the region, employees of private companies, members of the association of users…) and integrate them into the innovation process, motivating them to participate, putting the right tools in place to enable a bottom-up dialogue, and translating ideas into sustainable products or services. A toolbox has been developed, adapted to the needs of different companies and public authorities (crowd-innovation, lead users, service design, ethnography…).

In terms of **cost structure**, an evaluation criterion already suggested in the work of Mulder et al. (2008) and their 'Harmonization Cube' could be the "use of private versus public infrastructure." Indeed, being clear about the type of dedicated infrastructure for a Living Lab is key.

In the case of the Energy Living Lab pilot, the best location for its activities was determined to be in Chablais region *in situ.* However, the offices of the people leading this Living Lab at the University of Applied Science Western Switzerland were distant from the pilot region and did not suffice: different spaces were needed for stakeholders to meet, as well as to organize conferences or training sessions. In order to keep the costs down, the organizers had the idea to launch a co-working office in the region, in partnership with public authorities, partners of the Energy Living Lab. The funding would be based on a public and private partnership. Both workplaces embrace the same values, such as sharing ideas, tools, and infrastructure with the goal of developing social innovation projects in the region. The public authorities of the region proposed to host the Energy Living Lab and to share an existing office to diminish the costs at the beginning and to be immediately operational. A next step would be to launch a dedicated co-working space at a larger scale. Openness is also key to share resources developed by other living labs and diminish the operational costs.

In terms of the **customers segment**, the current ENoLL evaluation has no criteria linked to this thematic. Why is customer segmentation important? One can argue that in a Public Private People Partnership (PPPP) model, the focus on such a process is precisely on the relationship between stakeholders, to come to a shared vision, and to develop new products and services that contribute to sustainable lifestyles in a collaborative manner. What is less clear is how to identify a ‘customer’ for a Living Lab. In a collaborative process, this remains to be clarified. One type of ‘customer’ might be the group that will pay for the new product or service under development, but a ‘customer’ could also be a community that might benefit from a new type of product and service in terms of quality of life, for example, or even an entire region. Perhaps one way of understanding the customer segment is to identify the revenue stream of the Living Lab, as will be discussed in the following section. One tool proposed by the Digital Lifestyle Centre, a Living Lab based in United Kingdom (Wu, 2012) is the stakeholders’ map, which gives the opportunity to evaluate the segmentation of the different stakeholders between primary stakeholders – i.e., those at the core of the Living Lab, participating in its management and sharing the same values; as well as the secondary stakeholders, which benefit from the services proposed by the Living Lab. More research needs to be done to understand the ambivalent roles of the private and public partners.

In the Energy Living Lab pilot, the “customer” that would benefit from the co-creation in the region were planned to be three selected SMEs in the Chablais region. What has been imposed was an innovation challenge with an underlying sustainable development goal in the selected region in the energy field. During the workshop in January 2014, SME’s had the chance to present their needs. At the end of the workshop, mayors of the cities in the region were not completely satisfied by the proposed “challenges” in the pilot phase of the Living Lab. They communicated their own needs. They wanted also to be considered as “customers” benefitting from services provided by the Living Lab. In the applied research project, the public funding did not permit to do so. The research team decided to launch a new project submitted to the Swiss Federal Office for Energy to answer this need. Defining who is the “customer” of the Living Lab is not a trivial question and needs further researches.

The **revenue stream** is also particularly important for the longevity of the business model, and is a criterion not precisely assessed in the ENoLL evaluation process. One suggested evaluation criterion for the revenue streams comes from the work on the ‘Harmonization Cube’ and under services, where the others suggest to: “Organize the living lab as profit center” and also “links to business value” (Mulder, Velthausz, & Kriens, 2008). This point illustrates also the question related to the customer segment: who are the customers of the Living Lab and for whom is value created? If indeed value is created for a region, then the public sector might be considered an important source of revenue; if value might be created for private companies, they could also be seen as an important revenue source. Funding a Living Lab is considered as essential by practitioners as illustrated by Wu (2012) and in her analysis of 15 Living Labs in UK: "an agreed set of mutual benefits and goals among actors, as well as continuously available financial sources from public and private sectors is essential" (p.17).

Here, the question of '**sustainability**' is paramount, particularly regarding the longevity of a Living Lab. To launch a Living Lab under the leadership of a University, for example, with research funding, runs the risk that such an enterprise might need to stop at the end of the research project term, due to lack of continued funding. This was the case of the Food Living Lab in Switzerland, member of ENoLL. The same could be said for projects that benefit solely from private or public funding and that are too dependent on a sole source of funds. As new politicians enter their mandates and do not support anymore the LL with public funding for instance, which was the case for MobiLab in Geneva, a Living Lab without a diversified funding stream could be at risk.

In the Energy Living Lab, the revenue stream is a combination between public and private funding. The region itself contributes to the Living Lab in proposing office for the co-working area. The University of Applied Science is providing the seed money for the launch of the Living Lab and the test of the different methodologies and tools. Companies during the pilot phase in 2014 do not contribute financially but they are asked for a different contribution such as access to a community of users, organization of events in partnership with the LL, communication plan to disseminate the co-creation project… As of 2015, the companies wanting to collaborate will be asked to pay part of the innovation services provided, a co-funding if the challenge is related to an applied research project or the total amount if it is only a development project not linked to applied research. We believe that a Living Lab should identify the best revenue models for its operations, while also constantly assessing cost structure.

Finally, having gone through the process of creating a pilot Living Lab in 2014 through consultations with seven people interviews and by responding to the ENoLL 8th wave criteria, we can state the following strengths and weaknesses of the current process: we have noted that some of the Living Labs listed as ENoLL members were not running anymore and propose to further develop evaluation criteria linked to cost structure and revenue stream in order to assess the sustainability of future ENoLL members. Other sections of the Business Model Canvas concentrated the greatest numbers of evaluation criteria such as key partners, value proposition, key activities which were already fully evaluated.

2.6 Living Labs as Innovation Intermediaries

The Energy Living Lab case study illustrates the importance of the three missing elements, cost structure, revenue stream and customer segments, and proposed potential evaluation criteria based on empirical data. But it does not answer completely the question of what type of criteria to choose from, when evaluating a Living Lab's operations towards long-term longevity. From the European Network of Living Labs viewpoint, their 'customers segment' are the three different memberships: 348 Adherent members, 19 Effective Members and 3 Associate members. Only the effective members are paying an annual fee and benefit from the extended services of the network and are participating actively to the strategic development of the network. We make here the assumption that the objective of ENoLL would be to increase this "customers segment". But who are the effective members? How could ENoLL recruit more effective members during the next "wave" that are 'sustainable' and that make the network 'sustainable' as well? It would help to further define what type of additional evaluation criteria to select, when assessing the landscape of Living Labs.

This paper draws on a previous research on typology of innovation intermediaries proposed by Lopez-Vega and Vanhaverbeke (2009). They have defined four types of innovation intermediaries:

(1) "**Innovation consultants** provide innovation services, relying on internal sources of knowledge, to solve specific innovation problems or requests.

(2) **Innovation traders** screen and provide access to a large amount of external ideas and innovations, relying on a platform of innovation solvers, to facilitate the identification of potential scientific and business-oriented solutions.

(3) **Innovation incubators** provide infrastructures to facilitate the internal exchange of ideas and knowledge among firms searching to conduct science, technology or business activities.

(4) **Innovation mediators** provide infrastructures to facilitate the use of external ideas and knowledge coming from users, entrepreneurs, R&D institutes to established firms searching to conduct science, technology and business opportunities. »

Using this typology of innovation intermediates, ENoLL effective members have segmented into the four categories based on secondary data analysis available online: 4 members are considered as Innovation consultants, 6 members considered as innovation traders, 4 members considered as Innovation incubators and 5 members as Innovation mediator. We recognize the limits of this approach: this segmentation among the different types of innovation intermediaries would have been more precise with primary data. It is a first attempt to categorize them, further research would be necessary to ensure the categorization of each Living Lab, based on interviews with the members of these Living Labs to collect first hand data and complete the typology.

Based on this exercise, one can understand easily why it is so difficult for ENoLL to propose evaluation criteria for new LLs based on customers segments or revenue stream. The effective members belong to **different types of innovation intermediaries**. They have different types of customers segments and revenue streams. **There is no unique model to replicate from**. The proposed typology helps to understand the diversity of the network and the difficulty to set new evaluation criteria, across the board. The definition of what is a Living Lab is large enough to encourage this diversity, thus complicating the task of evaluating new postulations – but at the same time promoting the openness of the network, with 370 different members, encouraging diversity and not uniformity. It could favor the regional and thematic roots of each Living Lab, increasing the adaptation capabilities. Living Labs have a dynamic nature and will evolve over the time from one category of innovation intermediate to another.

2. 7 Conclusion

In this paper, we explore how Living Labs might be evaluated based on criteria that build on the current efforts of the European Network of Living Lab (ENoLL) to encourage new members in Europe, complementing their criteria with elements from business model development strategies – specifically the Business Model Canvas (BMC) (Osterwalder & Pigneur, 2010). Our main findings suggest that the BMC could be a complementary tool in evaluating Living

Labs, particularly in considering LL through the business model perspective. Considering this, **three elements are currently missing** or under-represented in the ENoLL evaluation system. These include **the cost structure, customer segments and the revenue stream**. We place this in relation to the creation of an Energy Living Lab in Western Switzerland. During this launch, standardization tools such as the Harmonization Cube are valued to build upon existing best practices. Most of the evaluation criteria give direction to practitioners in order to launch or consolidate a Living Lab in the network.

We then tried to better understand, with the help of the **typology of innovation intermediates** who are the actual effective members to better understand what type of evaluation criteria could lead to an increase in effective members that are active and alive. This model revealed the large diversity among the effective members, thus complicating the task of setting new evaluation criteria. It suggests a progression over the time from one category to another, an evolution that is not considered with the actual evaluation criteria. Different practical outputs could be raised: the necessity to evaluate the members over the time, not only when new LLs enter the network. If a member does not comply with the evaluation criteria, ENoLL should have the possibility to help the LL to be compliant or to dismiss the member. New evaluation criteria should also be set for the missing components, cost structure, customers segments and revenue stream, following a strategic reflection on how the network wants to grow, quantitatively or qualitatively? What are the common characteristics of the effective members? What type of new members are they looking for?

As Mulder et al (2008) put it, our goal has been to understand how to 'keep the living lab alive'. To encourage further research in this area, we would like to propose in the conclusion a few **additional dimensions** that might be considered in the creation and evolution of LL. First, the **time dimension**: we could like to suggest that a progressive approach be used in the evaluation of LL, that consider not only how a LL is created, but also how it is operationalized over time. Second, we would like to consider the **space dimension**, or how such LL are scalable (or not) and replicable (or not) to other spaces and geographic reaches. For example, Living Labs that work on a range of topics at the regional level might be evaluated differently from those that focus on a specific topic at the community level. For this, the cultural and institutional context should also be taken into consideration, including different institutional and legal frameworks.

This leads us to a third dimension, the **diversity and dynamic nature** of Living Labs. Organizations are evolving and could change from one type of innovation intermediate to another over time, not necessarily following a linear process. It is complicated to decide on fixed evaluation criteria with evolving organizations. Too narrow evaluation criteria could be a constraint for the development of the organization.

Finally, we hope that our research offers insights for others interested in creating a LL and insuring its existence over time. For the 'sustainability' of a LL, we argue that a strong model is needed, based on a long-term strategy that considers funding structures, target audiences, and revenue streams, among other important factors – all of which must be assessed not only at one moment in time, but over time, across a diverse range of LLs, in a continuous and dynamic process involving different stakeholders.

2.8 Notes of the chapter 2

The managerial impact of this article has been surprisingly (for the author) very important. ENoLL decided to screen the LL list of their network and to cut half of the adherent members, reducing the network from 370 to 150 members, due to stronger assessment. ENoLL is perceived as a **label** by its future members and if the quality of the assessment during the evaluation phase is not rigorous, the label could lose its credibility. The second managerial influence is on the evaluation and review process. New evaluation criteria have been proposed to compensate the missing categories (revenue stream, customer target, cost structure).

ENoLL has also launched the **Learning Lab** after a crowdsourcing process directed by the author among the members. The value of the network is to support the innovation intermediaries with educational activities toward their development.

A coherence in the approach, definitions, tools is crucial to structure the method. Definitions of LLs varies as the research is emerging to study the phenomena. After five years of studying the phenomena and a thorough literature search, the author proposes the following definition:

> *A Living Lab is an innovation intermediary, which orchestrates an ecosystem of actors in a specific region. Its goal is to co-design product and services, on an iterative way, with key stakeholders in a public private people partnership and in a real-life setting. One of the outcomes of this co-design process is the co-creation of social value (benefit). To achieve its objectives, the Living Lab mobilises existing innovation tools or develops new innovation tools.*

How could Living Lab play a role in co-designing energy conservation interventions and what would be the impact of this integration? This will be studied in this thesis.

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Chapter 3

Perceived value of energy efficiency technologies in a sustainable neighborhood: an empirical enquiry from the Energy Living Lab[10]

The launch of the ELL in 2014 was part of an applied research project financed by HES-SO internal strategic funds. The Article 1 has briefly described this launch. As the pilot project has been a success, a new project has been launched by the ELL team called UserGap. The goal of the project is to better understand the energy performance gap in low consumption buildings and to act on it with an intervention. The influence of users is central in this project. The Article 2 is the first phase of this project, the "social audit" before selecting a social practice that influence energy consumption.

This third chapter will be focused on the perception of the inhabitant of a sustainable neighbourhood on energy services. The first step in designing an energy conservation intervention is to choose a practice and to analyse it with quantitative and qualitative data. In this chapter, the mobility and heating practices will be the main social practices analysed. This paper was presented at the annual conference of ENoLL "Open Living Lab Days" in 2016. It has been published in the proceedings of the conference but not on the following special issue because it is not seen as a LL activity. It is preceding the co-design process.

[10] Draft version before publication

Perceived value of energy efficiency technologies in a sustainable neighborhood: an empirical enquiry from the Energy Living Lab

Mastelic, J., Genoud, S., Cimmino, F.M., Previdoli, D., Fragnière, E., (2016), Perceived value of energy efficiency technologies in a sustainable neighborhood: an empirical enquiry from the Energy Living Lab, Conference Proceedings, Open Living Lab Days 2016, Montreal.[11]

Abstract

The notion of a smart city combines technologies, citizen and a common sustainable vision such as for instance providing energy efficient buildings for a better life. This socio-technical system is built upon the assumption that better technologies will be perceived and drive citizen' satisfaction. But what if the technologies are not perceived by citizen? Or not driving satisfaction? We are interested in this paper in the perceived value of energy efficiency technologies by inhabitants of a sustainable neighborhood. As a methodology, we have first administered a survey to the inhabitants of a Swiss sustainable neighborhood. Then, we have analyzed rank correlations between the overall satisfaction and perceived value of energy services. An additional survey based on semi-directed interviews has enabled us to provide qualitative meanings to interpret these rank correlations. This research is exploratory since based on a single case study. The main conclusion is the following hypothesis: energy efficiency technologies are not perceived as a value as long as they are working properly. Based on this study, we intend to design a specific energy living lab configuration to be able to co-create energy efficiency technologies, involving energy consumers at the beginning of the value chain.

Key words: customer satisfaction, perceived value, sustainable neighbourhood

[11] Draft version before publication

3.1 Introduction

Europe has seen in the past decade numerous projects in the context of "smart cities". Part of these projects are led by technologies, integrating the citizen in a later stage (Dameri, 2013). This is also the case with the project presented in this paper. The underlying assumption in these projects is that better technologies will provide better quality of life. But what if the value of the provided technologies is not perceived? And what if the technologies are not direct drivers of satisfaction? This is what the authors want to test in this project in a swiss sustainable neighborhood.

The Swiss energy transition is based on three pillars, documented in the "Energy Strategy 2050" developed by the federal council (DETEC, 2015): (1) sobriety, (2) energy efficiency and (3) development of renewable energies. In this paper, we will focus on energy efficiency.

This paper presents the first phase of an pluridisciplinary applied research project about a "sustainable neighborhood" in Switzerland. This phase is intended to better understand the perception regarding energy services in a given Swiss sustainable neighbourhood. We will be using this neighbourhood as a living laboratory to identify new research hypotheses related to demand side management. We want also to understand energy consumption behaviors as well as the role of energy services in the satisfaction of living in the neighbourhood, composed of 400 apartments, parts of them is privately owned and part of them is rented.

This paper uses the **service dominant logic paradigm** (Vargo & Lusch, 2004) which emphasizes that what does create value is the service (sustainable living). Consequently, products (i.e. energy efficient technologies and buildings) are the vehicles that conduct the value to the consumer, the value is always co-created with the consumers when the service is consumed (if the service is not consumed, no value is created, such as for instance when the apartment is empty).

The buildings of the studied sustainable neighborhood have obtained the Swiss Minergie label, construction standard for new or renovated buildings[12]. The builders have indeed put a lot of emphasis on the energy consumption reduction of buildings and appliances. They have used

[12] *Qu'est-ce que Minergie ?* https://www.minergie.ch/quest-ce-que-minergie/articles/lessentiel.html

energy efficient technologies and materials. Moreover, there are no cars in the neighborhood (thanks to large underground parking slots) and public transportation is nearby. The population is mixed (owners, tenants, social housing, protected apartments for the elderly...). This paper focuses on the residents (unit of analysis), their perceptions regarding energy services, as well as their overall satisfaction to live in this pilot neighborhood in Switzerland.

The core research of this paper concerns the general satisfaction to live in the sustainable neighborhood under study and to learn whether there is a link between the provided energy services and the overall satisfaction. This variable is linked with other important factors like the Swiss label "Minergie". A further element is one of the specific characteristics of the studied neighborhood, the "no car concept". In fact, the cars can drive on the area's streets only for pickup services up to three times a month. All cars have to be parked in an underground central parking outside the area. The last compared element is the relationship between the satisfaction and public transportation. A bus commutes from this place to the railway station every half an hour.

The context of this research has led us to the following research question: **"Is there a link between energy services and the overall satisfaction to live in this sustainable neighborhood?"**

The methodology has consisted in administering a questionnaire to the households of the sustainable neighborhood under study. Even if the response rate is high regarding the whole population living in this neighborhood (164 residents have filled in the questionnaire, which corresponds to 34% percent of the apartments), we should consider this fieldwork to be a case study. Indeed, ultimately the goal of this research is to generate new research hypotheses that could be validated and generalized for other sustainable neighborhoods in further research. So first, based on inferential statistics, we identify which variables of the questionnaire are related together. Due to the qualitative nature of the variables used in the questionnaire, all bivariate hypotheses are defined over ordinal or nominal scales. Consequently, non-parametric statistical tests are applied and in particular rank correlations (i.e. Kendall Tau and Spearman's rho) since most of the retained bivariate hypotheses have variables defined over ordinal scales. To add "sense making" to the retained bivariate hypotheses, we have conducted a qualitative survey based on semi-directed interviews (that resulted into 29 transcripts).

The main finding of this research is that perceptions of energy services are not directly influencing the satisfaction to live in a sustainable neighborhood when the quality of energy services is good.

This short paper is organized as follows. In Section 2, we present the results of a literature review essentially based on the field of Service Science. This literature review is not exhaustive; however, it is intended to define the main theoretical concepts related to this applied research. In section 3, we briefly present the questionnaire and the sampling strategy employed as well as the qualitative research based on semi-directed interviews to provide meanings to the tested bivariate hypotheses. In Section 4, we test a few hypotheses relevant to the main theme of this paper. More specifically, we assess the link between perceptions of energy services and the overall satisfaction to live in a sustainable neighborhood. In Section 5, we discuss the main findings based on the data collected through 29 qualitative semi-directed interviews. In conclusion (Section 6), we indicate limitations of this study and directions for future research.

3.2 Literature review

As the topic of this paper is based on interdisciplinary research, we have developed a literature review based on the three following scientific domains:

- Sustainable lifestyle
- The notion of satisfaction as defined in Service Science
- The notion of perceived value as defined in Service Science

3.2.1 Sustainable lifestyle

Lifestyle for sociologists refers to "ways of life, choices and preferences, behaviors and attitudes, associated with various "social locations" or positions in societies and communities." (Lutzenhiser and Lutzenhiser, 2006). Gladhart, Morrison and Zuiches define lifestyle as the *"values, behaviors, practices, and possessions that are characteristics of a family"* (in Lutzenhiser and Lutzenhiser, 2006). For example, in the case of the studied neighborhood, we have young single people, young couples, families with small children, families with teenagers and retired persons. Sustainable lifestyle must thus fully be integrated in the neighborhood.

Dumreicher and al. explain that a sustainable neighborhood should be "compact, dense, diverse, and highly integrated" (in Jabareen, 2006).

The case study presented in this paper occurs in such a sustainable area. Furthermore, in this kind of area, the need for movement has to be reduced and environmentally friendly forms of transport have to be provided (Jabareen, 2006). To respect the Kyoto Protocol and to promote energy efficiency in buildings, many labels have been created in Europe (Mlecnik, Visscher and van Hal, 2010). As already explained in the context, the related label created in Switzerland is called "Minergie".

3. 2.2 The notion of satisfaction as defined in Service Science

The **satisfaction drivers** described in the service science field are, according to McDougall & Levesque (2000), the following three drivers: core service quality, relational service quality and perceived value as in Figure 17. These researchers have defined the customer satisfaction as the "overall assessment of the service provider while future intentions are stated likelihood of returning to the service provider". The relational service quality is defined as the way the service is delivered (McDougall & Levesque, 2000).

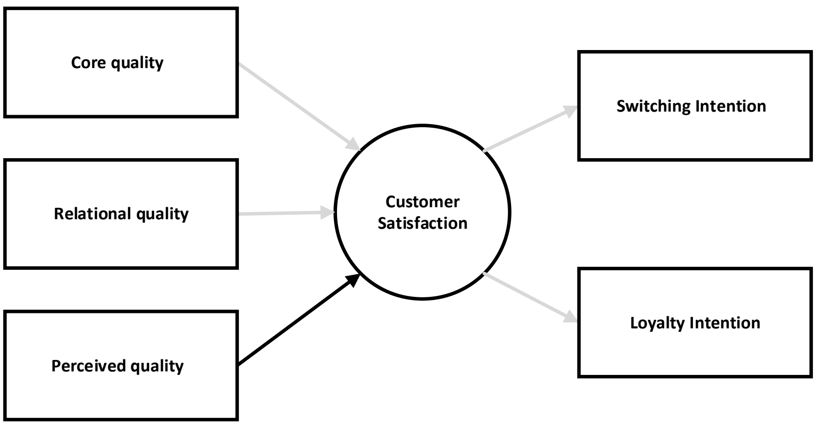

Figure 17. Role of perceived quality, adapted from McDougall & Levesque (2000).

In a residential environment, the level of residential satisfaction is often used to evaluate it (Cho and Lee, 2011, Anderson and Weidemann, 1991). This satisfaction is defined as "the experience of pleasure or gratification derived from living in a specific place" in the Theory of place in environmental psychology (in Cho and Lee, 2011). In this paper, we focus on the relationship between the perceived value and the customer satisfaction.

3. 2.3 The notion of perceived value in Service Science

The perceived value is generally defined as the "trade-off between what customers receive and what they give up to acquire the service" (Tam, 2004). The cost can be monetary or any other non-monetary costs like time, physical or psychic effort (Lovelock 2001, Tam 2004).

To **perceive a value**, the energy service needs to be tangible. Unfortunately, in most instances, it is solely when there is a bad service quality that the energy services become tangible (e.g. heating problem during the winter 2013 in the studied neighborhood). Kollnuss and Agyeman explain that the information about the environment damage has to be translated into understandable and perceived information like pictures and graphs (2002). In other words, for certain types of services, solely the negative perceived value becomes visible. This is especially the case for energy services.

Direct and indirect feedback literature could help to understand how to make the energy services more tangible. There is also a belief that relevant information will allow users to make better decisions (Shove, 2003). A meta-analysis has been conducted by the European Environment Agency. The advice of this agency is to combine direct and indirect feedbacks together. This advice has been applied in the studied neighborhood (i.e. a welcome folder that describes the vision of the sustainable neighborhood and how to consume less energy, smart meters with in home display, information presentation on the Minergie label, accompanied visits of the heating system, monthly energy invoices…).

3.3 Methodology

The methodology has consisted in administering a questionnaire to the households of the sustainable neighborhood under study. The data set is the result of an empirical inquiry in a sustainable neighborhood in Switzerland. A quantitative questionnaire was created and administered to the inhabitants of the neighborhood. The data collection from the residents was realized between mid-June to mid-July 2015. 164 residents have filled in the questionnaire, which corresponds to 34% percent of the population under study (i.e. apartments in the neighborhood). Reception of the questionnaire by the residents was done from June 19th to July 13th 2015. Ultimately, we have received 164 valid questionnaires: 156 in French and 8 in English, 115 by post and 49 by email.

In the collected sample, 74% of the respondents are renting their apartments. Moreover, 62% of the respondents have completed post-secondary education. Finally, the average wage is consistent with the rest of the Swiss population. Even if the response rate is high regarding the whole population living in this neighborhood we should consider this fieldwork to be a case study. Then based on inferential statistics, we identify which variables of the questionnaire are related together. Due to the qualitative nature of the variables used in the questionnaire, all bivariate hypotheses are defined over ordinal or nominal scales. Consequently, non-parametric statistical tests are applied and in particular rank correlations (i.e. Kendall Tau and Spearman's rho) since most of the retained bivariate hypotheses have variables defined over ordinal scales.

To add "sense making" to the retained bivariate hypotheses, we have conducted a qualitative survey based on semi-directed interviews (that resulted into 29 transcripts). The purpose of our research is exploratory and aims at generating new research hypotheses. The quantitative survey has been completed by 29 face to face semi-directed interviews with residents during autumn 2015. We selected a sample composed of satisfied and not satisfied residents: half of the sample was satisfied by the neighborhood and half of it was not satisfied. One third of the interviewed households are owners and the other part rent their flat. Half of the interviewee had a smart meter installed with an in-home display (tablets) and half of them had no smart meter. The goal was to deepen the understanding of the main hypothesis: value linked to energy services is not perceived when the core quality of the energy services is good. But if the core quality is considered as bad, a negative perceived value arises, influencing the overall customer satisfaction to live in the neighborhood.

3.4 Hypotheses Testing

We employ three different tests to verify the relationship between two variables: the Pearson correlation as well as two non-parametric tests of rank correlation, Sperman Tau and Sperman's rho. In this section, we have considered bivariate hypotheses related to our research topic and that are divided in the three following categories:

- Private transportation,
- Public transportation,
- Minergie label.

All bivariate hypotheses are handled such as the variables are qualitative. This is the reason why the hypotheses are all expressed using the term "relationship" instead of "correlation". Indeed, we will then rely on rank correlation that corresponds to a non-parametric statistical test.

Most of the defined hypotheses are linked with the variable "satisfaction". The following question were asked in the questionnaire: "Are you satisfied to live in this neighborhood?". The corresponding variable is defined over an ordinal scale as follows: very dissatisfied, dissatisfied, merely dissatisfied, merely satisfied, satisfied, and fully satisfied.

3.4.1 Private and public transportation

As explained earlier, private cars are forbidden in the neighborhood. Cars are centralized in a big parking place nearby, it can be rented. Inhabitants have access in the area with a badge only three times a month. We wanted to test the link between the variable "neighborhood without cars" and the general satisfaction to live in the neighborhood. As mentioned, 37,7% of the total energy consumed in Switzerland is used by transport (OFEN, 2015), mainly fossil energy. Transport has a huge importance on energy consumption and pollution. Here are the tested hypotheses: H0: there is no relationship between the variable "neighborhood without car" and the variable "general satisfaction". H1: There is a relationship between the variable "neighborhood without cars" and the variable "general satisfaction".

The first variable of the hypothesis comes from the following question in the questionnaire: "Are you satisfied with the concept of a neighborhood without cars?" The answer is defined over a discrete scale ranging from 1 to 6 (6 was the maximum). The second variable of the hypothesis is the satisfaction of the neighborhood, explained earlier. We employ three described different tests to verify the relationship between these two variables illustrated in Table 6.

Kendall's rank correlation tau			**Spearman's rank correlation rho**			**Pearson's product-moment correlation**		
	Satisfaction	**"No car"**		**Satisfaction**	**"No car"**		**Satisfaction**	**"No car"**
Satisfaction	1.00	0.43	**Satisfaction**	1.00	0.51	**Satisfaction**	1.00	0.53
No car	0.43	1	**No car**	0.51	1.00	**No car**	0.53	1.00
z = 6.6387, **p-value = 3.1e-11,** **Tau= 0.4312935**			S = 310598.9, p-value = 1.1e-11 rho =0.5090976			t = 7.6897, df = 154, p-value = 1.6e-12 cor = 0.5267292		

Table 6. Results for the correlation between "Satisfaction" and "No car".

Each test gives a p-value close to zero. Consequently, we have enough statistical evidence to reject the null Hypothesis. In terms of practical significance, we can see that there is a moderate positive rank correlation (Tau=0.43 and rho=0.51) between both variables neighborhood without cars and the overall satisfaction to live in this sustainable neighborhood.

3.4.2 Public Transportation

In the neighborhood, there is a bus every half an hour. The main train station is also not far away by feet (ten minutes). Public transportation is an important factor to reduce the fossil energy consumed by the inhabitants of the sustainable neighborhood. Following hypothesizes are tested: H0: There is no relationship between the variable "public transportation" and the variable "general satisfaction". H1: There is a relationship between the variable "public transportation" and the variable "general satisfaction".

The two linked variables are the proximity to public transportation and the satisfaction with the neighborhood. The latter comes from the previously explained question. The first one comes from the following question in the questionnaire: "In general, what importance do you give to the following when choosing your place of living? - The proximity to public transportation and the connection to the station?" The scale is defined as ordinal by 6 values starting from "not important" to "very important". Subsequent results are founded with the statics tests:

Kendall's rank correlation tau			**Spearman's rank correlation rho**			**Pearson's product-moment correlation**		
	Satisfaction	**Transports**		**Satisfaction**	**Transports**		**Satisfaction**	**Transports**
Satisfaction	1.00	0.25	**Satisfaction**	1.00	0.31	**Satisfaction**	1.00	0.35
Transports	0.25	1	**Transports**	0.31	1.00	**Transports**	0.35	1.00
z = 3.822, **p-value = 0.0001324** **Tau= 0.2536053**			S = 429138.9, p-value = 9.391e-05 rho =0. 308532			t = 4.5891, df = 153, p-value = 9.216e-06 cor = 0. 3478391		

Table 7. Results for the relationship between "Satisfaction" and "Transport".

Each test gives a p-value close to zero. Consequently, we have sufficient statistical evidence to reject the null hypothesis. In terms of practical significance, we can see that there is a low positive rank correlation (Tau=0.25 and rho=0.31) between both variables the proximity to public transportation and the global satisfaction to live in this sustainable neighborhood. There is a low positive influence between both variables. We can assure that if a person is satisfied with the neighborhood, he would be a bit more satisfied with the proximity to public transportation. As a reminder, the tests don't allow us to know which variable influence the other.

3.4.3 Minergie Label

The Minergie Label imposes criteria that the buildings must respect. One of them is to consume less energy than a standard building[13]. As mentioned in the introduction, room heating represents 65% of the total energy consumed by households, followed by water heating: 14.9% (OFEN, 2015bis). Efforts should be concentrated on building efficient and well-isolated apartments to decrease the total energy consumed in Switzerland. H0: There is no relationship between the Minergie Label and the satisfaction. H1: There is a relationship between the Minergie Label and the satisfaction.

The first variable of the hypothesis comes from the following question in the questionnaire: "What importance do you attach to the fact that your home is certified Minergie ECO?" The scale is defined as ordinal by six values starting from "not important" to "very important". The second variable of the hypothesis comes from the explained question about the satisfaction. We employ again the three different tests to evaluate the relationship between these two variables.

Kendall's rank correlation tau			Spearman's rank correlation rho			Pearson's product-moment correlation		
	Satisfaction	**Minergie**		**Satisfaction**	**Minergie**		**Satisfaction**	**Minergie**
Satisfaction	1.00	0.33	**Satisfaction**	1.00	0.40	**Satisfaction**	1.00	0.43
Minergie	0.33	1	**Minergie**	0.40	1.00	**Minergie**	0.43	1.00
z = 5.0767, **p-value = 3.84e-07** **Tau= 0.3349212**			S = 388798.6, p-value = 2.602e-07 rho =0.3971703			t = 6.0057, df = 155, p-value = 1.305e-08 cor = 0.4344774		

Table 8. Results for the correlation between Satisfaction and Minergie.

Each test gives a p-value close to zero. Consequently, we have sufficient statistical evidence to reject the null hypothesis. In terms of practical significance, we can see that there is a low positive rank correlation (Tau=0.33 and rho=0.40) between both variables. Again, if a resident is satisfied with the sustainable area, he probably attaches importance to the label.

[13] Minergie (2016). *Construire durable avec Minergie-Eco.*
https://www.minergie.ch/tl_files/download_fr/Broschuere_Nachhaltig%20bauen%20mit%20ME-ECO_fr.pdf

3.5 Discussion

It is interesting to notice that when asked about the neighborhood in general, what is satisfying and what is not satisfying, the respondents do not think spontaneously about energy services (heating, mobility, lighting, appliances...). Our main conclusion is that energy services are not spontaneously perceived as creating value and influencing directly the satisfaction to live in the neighborhood if it is working properly. It is as if these energy services are taken for granted. But when a problem arises, the energy services become visible and a negative perceived value influence the satisfaction to live in the neighborhood. Like Lovelock mentioned, the outlays to obtain a service are not only financial, but also time, physical and psychic efforts (2001). This affirmation is confirmed in our case study. Here are some examples from the qualitative interviews.

3.5.1 Minergie and Heating

During the winter 2013, the first winter after the construction, the district heating system was not functioning properly and the temperatures went down to 17 degrees, according to some residents, and the energy services became as such tangible. A negative perceived value influenced the overall satisfaction of living in the neighborhood. It was a technical problem that was solved quickly. But in the meantime, some of the respondents, not satisfied with the low temperatures, bought electrical heating systems to increase the temperature, which had a long-term impact on the overall energy consumption. It had also an impact as well in term of image of the sustainable neighborhood. Indeed, the respondents kept talking about it in a negative way one year and half after the heating problem during the interviews*: "I will not pay the heating bill if they send it, it was 17 degrees all winter!"* Heating has also been visible by the respondents because of a communication problem (relational quality). In this sustainable neighborhood, the temperature level is blocked to a maximum of 21 degrees inside the apartments: *"The problem with Minergie is that the temperature is very low (no more than 21/22 degrees), many people bring electric heaters in the apartment."* But part of the residents was not correctly informed about it (there are nine different real estate agencies in the neighborhood renting and selling the apartments). Worse, on the tool that controls the temperature, the scale was mentioning until 24 degrees. Some of the residents, not informed about the maximal temperature in the neighborhood, kept trying to increase the temperature the whole winter: *"I can increase the heat as much as I want, it does not exceed 20 degrees."*

This had also a negative impact on perceived value and overall satisfaction of living in the neighborhood: *"We have not been informed of the set temperature, we find this value totally arbitrary."* Only one person out of 29 interviews mention the good isolation (Minergie) resulting in heating decrease*: "We have only very, very little need to turn the floor heating on, because it is very well insulated."*

3.5.2 Public and private transportation

The sustainable neighborhood is conceived for pedestrians. Parking places can be rented by the residents and are also available for visitors in a separate building outside the area. At the beginning, residents were authorized to drive through the neighborhood when needed but only for a short amount of time (to pick up heavy goods for instance). But due to abuses, a barrier has been installed and new regulations of the neighborhood enable residents to access up to three times a month with a badge.

The mobility thematic has polarized the residents into two groups:

(1) People that came to live in a neighborhood without cars for ecological convictions or for security reasons (children safely playing in the streets). These are also mainly owners of their apartment that benefit from a parking place directly accessible under their building.

(2) People that came in the neighborhood for other reasons such as proximity to big cities or no other opportunity to find an apartment. It is mainly people that rent their apartment and have a parking place in the distant parking building.

One has seen in the hypotheses testing section that « neighborhood without cars » is moderately correlated with « satisfaction » to live in the neighborhood. Part of them is satisfied and part of them not satisfied. After analyzing the qualitative interviews, we easily understand that people, mainly owners, do not make any specific effort (underground parking). *"For now, we do not have access problem, but we do recognize the difficulty for some people, for disabled or elderly people, for example.* The children can play in the street, there is less noise during the night… We can see emotional salient attributes: a resident that do not want cars in the neighborhood used to install each weekend a tennis net across the street for the children to play and to block access to cars.

On the other way, for the people that do not benefit from a parking slot under the building and that have to walk with their shopping bags, children strollers, from the distant parking building, they need to make a special effort (especially "when it rains", as mentioned by a respondent): *"The restriction on cars cause enormous organizational problems especially with small children."* In case they have not chosen to live in the sustainable neighborhood because of their ecological convictions, it is even worse. The negative perceived value is strong, and they talk about leaving the neighborhood. One of the respondents, blocked by the tennis net, decided to sue that person to stop this practice. The negative emotional and logistic salient attributes appear strongly during the interviews. And as well for the image of the sustainable neighborhood, it can have an important impact on the general ambiance.

3.5.3 Information tools

It has been mentioned that energy services are not tangible and to perceive a value, it is important to make them more tangible. Direct and indirect feedbacks have been proposed in the sustainable neighborhood. Different types of information tools have been supplied in the sustainable neighborhood: (1) a folder that contains all the information about the neighborhood: the initial project, the vision of decreasing energy consumption, advices on how to diminish the consumption… (2) Thematic visits by a neighborhood guide that was hired during two years by the construction company. One of the visits was for instance an explanation of the district heating system. (3) A smart meter integrated in an in-home tablet (it controls the opening of the door, the temperature of each room, it gives information on the public transportation schedule, weather report and energy consumption).

We found that only seven people, out of 164 that answered the survey, declared they did not use any kind information provided. Most residents were informed about energy services. From the quantitative inquiry and the qualitative interviews, we can say that the provided tablet is « a nice to have »: *"it is very nice to have the tablet, but I do not use it."*. But the perceived value of these information tools is not very high: the smart meter has been considered as a "gadget": *Friends and acquaintances who came to visit the apartment would always ask at the beginning to see the tablet, but it's still a gadget".* If the energy services are of good core quality, the perceived value of energy services seems to be low. We could thus say that energy is not a main concern and that the residents do not feel they need more information about it. It is to mention the cost of energy as well which is low: *"As long as the bill remains very low, I do not change* *my behavior."* It does not mean that their energy consumption is not influenced by this information. One person mentioned: *"No need to watch my consumption every day. But during the heating problem, thanks to the tablet, we could see that the heater was running at full speed."*

3.6 Conclusion

A sustainable neighborhood is defined as an urban area involving modern ecological concepts. The impact on the environment is thus an important attribute of a sustainable neighborhood and thus energy services consumption should be related to it. In this paper we want to test whether there is a link between energy services perception (heating and isolation, public and private transportation…) and the overall satisfaction to live in this sustainable neighborhood.

To investigate this research question, we have first administered a questionnaire to the inhabitants of a Swiss sustainable neighborhood. We have then analyzed the rank correlations between the level of satisfaction of living in a sustainable neighborhood and elements of perceptions regarding energy services like private and public transportation and high energy efficiency human habitats. We see that all the tested rank correlations are statistically significant. However, the practical significance in terms of Kendall's tau and Spearman's rho is always quite low.

This survey is complemented by 29 semi-directed interviews to provide additional meanings grounded on the field of Service Science. It seems that the typical salient attributes (i.e. main elements of perceived value) of a sustainable neighborhood is not visible or tangible when it is about energy services consumption. Consequently, the main finding of this research is that perceptions of energy services are not directly influencing the satisfaction to live in a sustainable neighborhood when the quality of energy services is generally good.

The limitation of this research is that it corresponds to a case study. Indeed, its main purpose is to generate new research hypotheses related to the perception of energy services within the context of sustainable neighborhoods. In a further research, we intend to conduct a survey involving more sustainable neighborhoods to be able to generalize our results and make inferences. Although this research is purely exploratory and cannot be generalized.

It advocates that sustainable neighborhood must be properly designed in order to better "tangibilize" energy services.

After this first analysis of the situation, the next step of this applied research project is to set up an Energy Living Lab in the neighborhood, with the public authorities of the city, the building constructor, the energy utility and the inhabitants. The objective would be to develop incentives with the inhabitants toward energy conservation in the neighborhood. Furthermore, as seen in this case study, information on energy services did not seem to guarantee that the residents perceive the value of these services. How to make energy services more tangible is an open question for researchers and managers that provide these energy services and technologies.

3.7 References of chapter 3

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Chapter 4

Living Lab as a Support to Trust for Co-creation of Value: Application to the Consumer Energy Market

The fourth chapter will introduce the concept of trust as a fundamental element to support the co-design process. A first review of the literature will define the concept of trust and its main components. Two case studies of Living Labs co-designing energy services in different contexts will be analysed separately with the prism of trust and then compared. From these two perspectives, an enhanced co-design process, the Co-coon Matrix, has been developed and is proposed in this paper, accepted in the Journal Innovation, Economics and Management from the editor DeBoeck Superior[14]. It is exploratory and needs further development but could be an important managerial contribution for the development of co-designed energy services.

[14] Draft version before publication

Living Lab as a Support to Trust for Co-creation of Value: Application to the Consumer Energy Market

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Abstract

Open Innovation is widely explored, and many technologies are developed to support the involvement of stakeholders in its distributed co-design process, i.e. when actors work asynchronously and at a geographical distance. One of the fundamental parameters for the success of distributed collaborative approaches is the trust that the actors have in each other, in the current process and in technology. However, practitioners make little use of trust as a parameter for piloting and supporting co-creation of value. The lack of understanding of the mechanisms involved seems to explain this situation. Using a multiple-case-study analysis of co-design in the field of energy, this paper proposes to identify the levers in Living Lab favouring the trust between stakeholders. In addition to practical illumination, this paper provides a first co-design project management framework for practitioners, through the development of the "Co-coon Matrix".

Keywords: Trust, Open Innovation, Living Lab, Co-creation of Value, Co-design.

JEL Codes: O31, O33, L17

[15] Draft version before publication

4.1 Introduction - The challenge of co-creation of value

Chesbrough (Chesbrough, 2003, p. 43) introduced and defined the concept of Open Innovation (OI): "*Open Innovation means that valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well.*" OI is a company-centric paradigm, the aim of which is to open the boundaries of companies' R&D departments to the outside world. This concept and its related practices are now widespread in the socio-economic world. In this context, the challenge is no longer to disseminate OI but rather to identify the levers to strengthen it, relying in particular on the areas linked to this flagship concept. Different evolving literature streams co-exist in parallel with OI, such as User Innovation (UI) or User-Driven Innovation, which we will address through Living Labs (LL) (Schuurman, 2015). User Innovation is clearly consumer-centric (Von Hippel, 2005). The aim is to co-design products and services with its users. As proposed by Schuurman, the Living Lab concept is at the intersection of OI and UI. To co-create value with the external world, the company's boundaries must be porous enough to facilitate the exchange of ideas, concepts or prototypes, whether it is an outside-in or inside-out exchange. Tools and techniques provided by UI are used in OI contexts.

Within an organization, OI underlies a twofold process of openness. (1) The first level of openness concerns project teams in the upstream phase of innovation, whose members are expected to interact regularly in an iterative way with the end customer, or even the user of the product or service that is in the co-design process (Sanders and Stappers, 2008). In addition, the organization itself must be part of an OI process requiring interaction between teams and all or part of the organization with its ecosystem (suppliers and economic, institutional and academic partners etc.) It is no longer a bilateral relationship between the company and its users but numerous interactions in a complex ecosystem of actors. In LLs, the model used to analyse a typology of actors is named the Quadruple Helix, composed of companies, public authorities, academics and citizens (Arnkil *et al.*, 2010). Thus, the increased recognition of inventiveness and innovation as essential differentiating factors in an increasingly competitive world, the rise of the collaborative economy involving sustained exchanges between peers and the strong interest in introducing a principle of co-design into innovation projects strengthens, disseminates and even invites us to rethink the OI, interpersonal relations and governance.

In such a complex system (Kurtz and Snowden, 2003), in order for the co-design process to function and develop in an optimal and fluid way, it is useful to identify what can stop or – on the contrary – stimulate the motivation of individuals to engage as co-designers or at least contributors with a process over which they seem to have no control.

This paper focuses on the links between trust, the co-design process and co-creation of value. Indeed, research shows that trust is a key success factor in the development of organizations and the integration of users into OI processes, as we will see in the next section. In addition, (Greco *et al.*, 2017) highlight the potential contributions of OI to the energy sector with the key role of five variables: (1) government involvement, (2) university involvement, (3) customer and supplier involvement, (4) absorptive capacity and (5) innovation novelty. More specifically, in the world of energy distribution, co-design (for example, the design of new technology or new services) represents an opportunity for the development of customer relations and value co-creation. Numerous benefits of co-design have been mentioned by (Steen *et al.*, 2011, p. 58), who categorize it in four groups: "*Improving idea generation, improving the service, improving project management and improving longer-term effects*". The challenge is to put the user at the centre of energy innovation, at the beginning of the value chain, in trades and practices that are more oriented towards technological innovation (Dupont *et al.*, 2017). This evolution of the context offers the opportunity to understand, and even measure, as soon as possible in the arrival of new practices, the contribution of user integration to the innovation process in the field of energy services.

Given the novelty of this field, as described in the research design part, we have decided to adopt a research approach based on multiple-case-study analysis. Thus, through two energy-related case studies, we will illustrate how trust is a major issue, particularly in situations where projects are based on research by a wide diversity of actors, including users, in both quantity and quality (i.e. fields of expertise, focus of interest). The discussion part proposes to highlight and articulate specific Living Lab functions that promote trust in the co-design process to support the co-creation of value. The challenge is to verify that an idea is appropriate or rejected for what it is, and not because of the co-design process followed, the technology used to bring it out and represent it or because of the initial actor who carries it. Through the outline of a functional specification (Pohl, 2010), we will more specifically highlight the characteristics that a co-design process must offer to stakeholders.

4.2 The challenge of trust for innovation

4.2.1 Trust: an essential lever for inter- and intra-company innovations

As already explained by Koschatzky (2001, p. 6), "*firms which do not cooperate and which do not exchange knowledge reduce their knowledge base on a long-term basis and lose the ability to enter into exchange relations with other firms and organizations*". This observation is now widely shared by the OI scientific community. Nevertheless, the quality of this cooperation remains a challenge for companies to increase innovativeness and further reduce time to market. Working on the robustness of the process can be beneficial, for example by ensuring that it is more in line with users' needs. The co-design process can also become more eco-responsible by mobilizing processes that respect the principles of sustainability by favouring short channels, socially responsible choices, the well-being of employees, etc. One of the common denominators of all these areas for improvement is trust. It is found at all levels of an organization and can be a lever for development: trust between peers in a community of co-designers, trust between companies and external contributors, trust between a company and its employees, trust between partners, trust in the methods and tools underlying the innovation process.

Trust contains three dimensions (Mayer *et al.*, 1995): (1) benevolence (the perception of a positive orientation from one person towards another); (2) ability (group of skills, knowledge, know-how in a particular domain); (3) integrity ("relates to the perception that the other party adheres to a set of principles and values that the trustor finds acceptable, such as delivering on promises" (Shazi, Gillespie and Steen, 2015)). Taking these principles into account, it can be seen that several levels of maturity in terms of trust can be observed and developed within companies and their partnership relations. Thus, researchers propose a model that ranges from "limited trust" to "collaborative trust" (Fawcett, Jones and Fawcett, 2012).

Within companies, the research of Pirola-Merlo (2010), using West's "innovative team climate" model, shows that there seems to be a positive correlation between a team's climate and the speed of completion of a research and development project. Four dimensions characterize this climate (West, 1990): (1) the sharing of clear and valued objectives; (2) a non-threatening environment where members can influence discussions and decisions; (3) the pursuit of excellence through quality work and critical evaluation; (4) the valuing of innovation and supporting of working practices to achieve innovation. (West and Sacramento, 2006) recall that some authors consider that learning and innovation can only take place when group members trust the intentions of other members.

In 2014, a study conducted on a panel of 48 member companies of the German Maintenance Services Association showed that three elements are needed to achieve a medium to high level of innovation: contracts, trust in a supplier to respect collaboration and ability to fulfil the obligations agreed between the parties (van der Valk *et al.*, 2016). This same study showed that in order to reach certain levels of innovation, certain thresholds must be respected for each of these three parameters. Under certain conditions, innovation performance depends very directly on the level of detail of contracts and the quality of trust established between partners. At the enterprise level, the establishment and maintenance of trust-based-relationships in B2B reduces risks, transaction costs and long-term relationships (Dovey, 2009). This is particularly true for innovation and creativity processes (Shazi *et al.*, 2015).

Innovation requires creativity and a certain amount of risk taking, so the results are uncertain and unpredictable, making it impossible to draft precise terms and clauses of a contract in advance. More flexible mechanisms are needed to guide a partnership or collaboration, in which it is necessary to balance trust between partners and the establishment of contracts. In addition, a 2011 survey (Wang *et al.*, 2011) of 315 Chinese companies shows that while, in certain circumstances, contracts and trust can replace each other and guarantee the same performance, in situations of uncertainty trust between the parties is much more effective than the (costly) implementation of contracts. Managing an OI project requires the ability to understand and anticipate the environment in which the project will be deployed.

Furthermore, researchers underline the role of trust at the macro level. Indeed, they demonstrate that societal trust promotes firm innovative efficiency in an open innovation context (Brockman *et al.*, 2018). Plus, according to Nestle et al., "*trust turns out to be a significant facilitator of open innovation cultures*" in firms of a German high-tech cluster (Nestle *et al.*, 2018, p. 7). This research on systems of innovation suggests that adequate infrastructure supported by local governments and a dedicated cluster manager could promote network activities and establish mutual trust between actors of firms.

Finally, the literature highlights the importance of addressing trust to promote business innovation processes, the culture of open innovation, and potential economic dynamism. At the same time, the state of the art shows that little work is being done on this topic. Thus, the relationship between users, trust and open innovation would benefit from being better studied and understood to improve the process of co-creation of value.

4.2.2 Trust at the heart of user engagement and collaboration in Living Lab

Living Lab is a recent phenomenon. Research on Living Labs still needs structuration and an "*Organizing Proposition*", which is true of all newly researched phenomena, as mentioned by Davis in his seminal paper, "That's interesting" (Davis, 1971). In 2015, Schuurman proposed a structuration different from Pallot et al. (Pallot *et al.*, 2010) *LL research landscape*, with an interesting model separating three layers: the macro, meso and micro level, as in Table 8.

Level of analysis	Definition in LL terms	Literature streams
Macro (system)	Living Lab constellation consisting of actors (PPP partnership) and infrastructure	Open Innovation
Meso (project)	LL innovation project	Open & User Innovation
Micro (stage of the project)	LL methodology consisting of different research steps	User Innovation

Table 8. Different levels of analysis in LLs, adapted from Schuurman (2015).

The macro level of Table 8 refers to the "Open Innovation" stream, with the constellation of actors in a public-private-people partnership. The meso level represents the innovation projects. The micro level refers to the "User innovation" stream and is composed of the LL methodology. Definitions of LLs vary, as the research is still emerging to study the phenomena. Mastelic proposes the following definition of Living Labs in her doctoral thesis on the subject (Mastelic, 2019, p. 58). *A Living Lab is an innovation intermediary, which orchestrates an ecosystem of actors in a specific region. Its goal is to co-design products and services in an iterative way, with key stakeholders in a public-private-people partnership and in a real-life setting. One of the outcomes of this co-design process is the co-creation of social value (benefit). To achieve its objectives, the Living Lab mobilizes existing innovation tools or develops new innovation tools.* Without a co-design process, the phenomena cannot be termed "Living Lab".

Observational studies can be mobilized to better understand the social practices but, by themselves, they cannot be considered as innovation tools used in LLs. Without the Quadruple Helix represented in the partnership (Arnkil *et al.*, 2010), a project is not considered a Living Lab. Public authorities, academics, private companies and citizens must be part of the ecosystem of actors that co-design products and services. Each actor has a specific role and does not participate in each phase of the co-design process (idea, concept, prototype, product); a selected group of actors are involved, depending on the goals of each step, coordinated by the LL manager.

The notions of trust and contract are strong issues in LL. Indeed, LLs as innovation networks require the establishment of strong links of cooperation and collaboration. In the context of LL, this cooperation is done with the users who are at the heart of the projects. From experience, (Guidat *et al.*, 2011; Dupont *et al.*, 2014, 2015; Dupont *et al.,* 2015; Mastelic *et al.*, 2017), we can point out that projects in LL mode induce tacit contracts between participating users, project leaders and potential method leaders without being able to guarantee the intellectual (and/or industrial) property of what could be produced. In addition, the mobilization of actors is generally based on mutual trust, which must be built and nurtured.

We suggest transferring the work of Shazi, Gillespie and Steen (2015) on innovation networks within business projects to LL projects. Thus, we recognize that users bring different skills depending on the subject and the time of mobilization (diagnosis, idea generation, feedback, etc.) to provide expertise and know-how useful for innovation. On the other hand, in all cases, their benevolence is required and necessary. It remains a nodal point in the relationship being built. Research shows that integrity is also a fundamental characteristic. A competent employee who lacks integrity will be actively avoided in the setting up and development of innovation projects. Our experience with LL projects has confronted us with some recurring questions from user participants in relation to project sponsors: What will be done with our contributions? Do we serve the general interest or a particular interest? Will our expression be respected? Conversely, project leaders who adopt a LL approach aimed at involving users in their approach sometimes wonder about the integrity of the actors who will join them: will they respect a certain confidentiality if it is required? Will they be in line with our values? Will they be "sincere" or "authentic"? In practice, since it is impossible to verify *a priori* the full interoperability between participants, facilitators and project leaders, it is necessary to accept that actors withdraw or are excluded during the process.

4.2.3 Co-creation of value and trust: forgotten by collaborative environments?

What do we mean by co-creation of value? When a company decides to open the boundaries of its R&D department to the outside world (OI), and to put in place a co-design process with its users (UI), the goal of this process is to co-create value. We see the co-creation of value as the outcome of a co-design process. As Vargo and Lusch express it, there is no value created until the service is consumed (Vargo and Lusch, 2004). The consumer is always a co-creator of value. In a co-design process, the user becomes a co-designer and is integrated at the beginning of the value chain, in the "*fuzzy front end*" (Sanders and Stappers, 2008).
A study conducted in 2018 on collaborative immersive environments (Dupont *et al.*, 2018) provides interesting insights into the notion of trust and co-creation of value. Collaborative immersive environments include tools, methods, digital systems (from Web 2.0 to immersive devices), or even physical spaces that allow and facilitate the work of groups composed of eclectic people, distributed or not, in synchronous or asynchronous work (Recker *et al.*, 2013; Tran, 2014; Bayrak, 2015; Dupont *et al.*, 2018). The analysis, based on 23 scientific articles published since 2000 in international journals and one thesis, highlighted four recurring dimensions for Collaborative eXperience: (1) Sense Making; (2) Trust Building; (3) Shared Meanings; (4) Mutual Understanding. This study also identified two properties by dimension, respectively: context understanding and relevance; interpersonal relationships and trust; knowledge sharing and knowledge creation; group dynamics and collective intelligence. Dupont et al. (Dupont *et al.*, 2018) reveals that two properties are not very well researched: trust and knowledge creation. The small number of studies on collaborative immersive environments that focus on these properties raises questions about the importance given to concepts that are at the heart of collaborative processes, which are by nature open and by nature part of a knowledge creation process, consubstantial with the innovation process.

The various elements from the literature underline the fundamental nature of trust for each member of a company, for example through the belief in his or her own abilities. Trust between the members of a company is also necessary to ensure balanced and profitable relationships. Trust must therefore be found between the hierarchical and functional levels. Finally, loyalty is an essential factor in an organization's relations with its partners and other stakeholders in its environment, particularly when it comes to involving users in the process. More generally, it is also a question of having confidence in your market and your ability to adapt to more or less predictable changes.

Despite the relevance and clarity of these findings, it still seems difficult to establish and maintain relationships of trust. Although context and technology can respond to a number of challenges on an ad hoc basis, there are still obstacles to overcome in order to strengthen trust at the different levels we have been able to identify. It seems necessary to understand and equip the processes of the upstream phase of innovation to ensure an OI process that fills the gap.

4.3 Research Design

4.3.1 Multiple-case studies from longitudinal exploratory research

In this article, we adopt a multiple-case-study approach (Yin, 2018). Indeed, we focus on contemporary events over which we have no control and our research questions are more explanatory and deal with the tracing of operational processes over time. In fact, we want to know "how" and "why" our living labs had worked (or could work better). In particular, we focus on the "trust" variable in two Living Lab projects. Thus, this method allows us to shed light on the question of trust through the complementary analysis of two case studies of OI applied to the field of energy services for two European countries (Switzerland and France), both of which have been the subject of a Living Lab initiative over a relatively similar period. Fell proposes the following definition: *"Energy services are those functions performed using energy which are means to obtain or facilitate desired end services or states"* (Fell, 2017, p. 137). The innovative nature of the deployment of OI approaches for companies in this industrial sector encourages us to capitalize and analyse concrete experiences to develop and characterize transposable methodologies. This work also allows us to provide additional analyses to the research of Greco, Locatelli and Lisi (Greco *et al.,* 2017) who deplore the small number of studies on OI for companies in this sector. Europe is putting in place an energy transition based on two main pillars: (1) energy efficiency and (2) the development of renewable energies. 40% of the energy consumption is related to the building sector in Europe (European Commission, 2013). Ambitious goals are set at the European level: "*by 31 December 2020, all new buildings are nearly zero-energy buildings"* (European Commission, 2013). The energy sector is still traditional and focused mainly on technological innovation. Cases of OI in the sector are emerging, closely linked to Smart City initiatives in Europe. In the LL network, for example ENoLL, actors are developing action research projects such as the Lorraine Fab Living Lab® and the Energy Living Lab. In this research, we use three data collection sources: (1) individual perceptions from researchers; (2) individual and collective behaviours and attitudes observed during the project; (3) process outcomes (how and why it works). The data collection used different sources of evidence: (1) documentation such as research papers or reports from the projects; (2) archival records as capitalized ideas; (3) direct observations from researchers; (4) participant-observation as researchers involved as makers; (5) physical artefacts as well as digital and physical platforms.

The first case presents part of the results of a longitudinal exploratory study conducted during the creation of the Energy Living Lab (ELL) in Switzerland, whose challenge is to create an innovation ecosystem to promote the co-design of energy services for one of the 700 energy distributors.

The second case presents the French project Link by Makers (LbM) of the University of Lorraine. This project, driven by academics and makers (i.e. members of a FabLab), received the support of ENEDIS, the French electricity distributor, and Université de Lorraine (Chair REVES project), as a way to experiment with some form of OI in connection with the smart meter installed by the distributor who manages 95% of the French grid.

Two different teams of researchers designed these cases independently. Nevertheless, they adopted the same living lab approach on the same topic. The first team, involved in a Swiss LL, conducts research on marketing and innovation management. The second, engaged in a French LL, does research on industrial engineering and innovation management. The two case studies that we will detail below emerged in different local contexts, but in both cases the researchers considered that the stakeholders concerned in each situation trusted each other. They also assumed that users trusted the process set up by academics to generate a real co-design dynamic. The first work presented independently validates the ability of processes to generate co-creation of value. The cross-referenced analysis of the two teams' feedback on the implementation and management of these two cases allows us to return to the premise of the trust placed *a priori* in the process by the stakeholders. The latter is not automatic. Barriers to change can be avoided. Good practices have been identified to establish a climate of trust between stakeholders in an innovation process that is open over periods of six to eighteen months. Finally, it seems possible to use technological levers to accelerate this innovation process and guarantee its agile nature.

4.3.2 Case study 1: The Energy Living Lab, lack of trust as a limit to the co-design of energy services

This case study describes one of the first projects of the Energy Living Lab. It began in autumn 2013 and lasted two years, in a context of transition in the Swiss energy sector. Indeed, during this period, distributors will move in the near future from a monopolistic status in their jurisdiction, with captive customers, to a competitive context, in which customers are free to choose their energy distributor. The challenge of this ELL project is to use co-design to develop energy services and co-create value for the partner company. The method followed is structured in four steps: (1) the formulation of the challenge, (2) the co-creation platform (www.i-brain.ch), (3) the target audiences, (4) the nature of the data collected, as well as the successive steps of data processing and analysis. This case has been described in a previous paper (Dupont *et al.*, 2019) and Figure 18 shows the co-design process and its outcome (co-creation of value) stage by stage, supported by specific technologies.

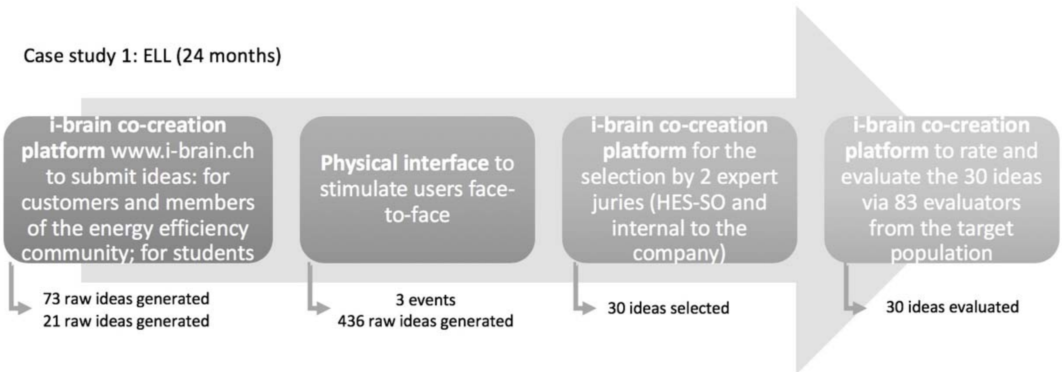


Figure 18. Sequential vision of the complementarity of the support platforms for co-creation within the ELL project, adapted from (Dupont et al., 2017)

Users' interest in co-creation of value was measured by the number of ideas submitted by users in the different contexts (physical and virtual interfaces). The number of responses desired by the economic partner was achieved, but it was necessary to switch from the virtual interface to a physical interface in order to stimulate face-to-face users (see Table 9). The challenge presented had to be explained during these interactions, which could suggest that the question was too technical or complex, and that it was not appropriated by users, which could have been a barrier to participation via the virtual interface. The research team hoped that the participation rate through virtual interfaces would be higher. Their confidence in the ability of users to address this issue individually and virtually was overstated.

	Distributor's customers	Members of the energy efficiency community	HES-SO Bachelor's and Master's students	Total
Number	30,000	5,000 (some of which may be from customers)	4,707	between 30,000 and 39,707
Participants	Around 500			Around 500
Ideas submitted via Internet platforms	73		21	530
3 Dedicated events	436		Not Concerned	
Origin of the selected ideas	21		9	30
Average of the scores assigned (via Student test)	7.59 points		8.12 points	7.74 points

Table 9. Synthesis of the results of the co-design process implemented by ELL.

The ideas selected by the company nevertheless raise several technical, legal or operational issues and the company carries out further analyses to confirm their feasibility and, if necessary, the implementation modalities. It should be stressed, however, that no ideas proposed were considered to be really new and many of them were redundant, which is not surprising in an idea generation phase where the aim is to understand the latent needs of users. These raw ideas must then continue a long way in the innovation process to be transformed into concepts, then into prototypes and finally into services. The critical phase is to continue the design of the service after this ideation phase within the company, at which point the risk of the "*not invented here syndrome*" (Chesbrough, 2011) may appear, which is characterized by the rejection of ideas not generated within the company and blocking the process.

The company's approach underlines the company's clear desire to integrate the user at the heart of the discussions; the profound changes that the energy market in Switzerland is undergoing have a direct impact on the company's internal culture and a genuine global opening strategy makes it possible to prepare it for market liberalization (the implementation of an Internet exchange platform, which is at the same time informative, incentive and collaborative, is now a testament to this global approach which has been initiated).

Physical interfaces seem to yield a greater number of ideas than purely virtual interfaces. Three hypotheses could explain this point: (1) the energy is not "*top of mind*" with the users questioned and it is necessary to stimulate the group face-to-face so that it gives ideas, (2) the challenge posed was badly formulated and not very comprehensible for non-experts, (3) the virtual interface does not offer enough guarantees in relation to the uncertainty generated by the approach (need to reassure and to quickly respond to the questions or misunderstandings that direct physical relations generate).

The group solicited seems to have an influence on the number and quality of ideas submitted. The student group submitted more ideas in proportion to the number of people invited. Ideas from this group were considered to be of better quality (more ideas selected on a *pro rata* basis in proportion to the ideas submitted). The company that participated in the research has recently begun to change its relationship with its customers in view of the forthcoming liberalization of the electricity market for households in Switzerland. It is possible that the relationship of trust and loyalty is not yet strong enough for customers to engage in co-creation of value via a digital platform. Because, as (Cova and Cova, 2009, p. 95) highlight*, "the process of governance underlying the new consumer's discourse must remind companies that they must not believe that all their customers have succumbed to the formatting of the creative consumer and that they all now have the skills to dialogue, play a role and integrate the company's offers",* this process takes time and requires several iterations before they can transform their customers into change agents.

The divergent opinions of the expert groups can be explained by various hypotheses; the internal jury is under the influence of a latent internal strategy, a realism as to the applicability of the ideas suggested or a *"time-to-market*" reflection. However, there is no evidence that the composition of two external and homogeneous juries would have led to selections of converging ideas: the flexibility left to the juries as to the organization of the selection process accentuates the exploratory process of such a study. This may also be due to the *"not invented here*" syndrome mentioned earlier. However, the interest in seeking ideas from outside the company, as Chesbrough points out, is to overcome this syndrome by working on openness, particularly in a monopolistic environment. We therefore come back to the question of the trust

of the company's members in the outside world.
If the Swiss case study allows us to understand the intangible dimension of creativity through a process of generating raw ideas, the French case study on the smart meter allows us to deepen the transition from idea to prototyping in a context of mobilizing very eclectic actors among a population that is not clearly identified.

4.3.3 Case study 2: Linky by Makers, building trust between industry, academia and makers

Between 2013 and 2022, ENEDIS is to deploy 35 million smart meters in France. These meters are the property of the electricity distributor. The meter itself is in the process of being installed for commercial operation. The "smart meter" product can be described as "finished" but the smart grid system will only be fully operational when all the meters are installed in French territory. Furthermore, the ongoing technological and industrial transition and the issues it raises generate controversy (Assemblée Nationale, 2016) that we will not study here.
Linky by Makers (LbM) examines the use of smart meters and smart grids (http://linkybymakers.fr/in-english/). This national project began at the end of 2015 during an exchange between industrialists, academics and makers within the Lorraine Fab Living Lab® (LF2L). At the instigation of Nancy-based makers networking with other French makers in five French regions via five "Regional" FabLabs (FLR), this project, initially planned for six months, was extended by 12 months in part because of trust issues.
LbM is based on the principle that academics, consumers and suppliers can work together (Carayannis and Campbell, 2012), in particular to understand the uses of a technology that is still little known to the greatest number of people, even though we are all electricity users. The experimental project posits the following hypothesis: makers who are used to "tampering with" could: (1) be an avant-garde community that enriches the understanding of the possible uses of the meter (via additional developments in open hardware); (2) support reflection on new forms of production/consumption/use of electricity from so-called smart grids.
The project's objective was then to allow the French FabLabs, or those who considered themselves makers, and who were interested in the question of energy, to take up this challenge themselves. The University positions itself as a research support to help stakeholders communicate with each other and share ideas, as well as capitalize on and analyse the

experience.

Different aspects of this case have been described in two previous papers (Dupont *et al.*, 2017, 2019). Figure 19 focuses on the co-design process and its outcome (co-creation of value) stage by stage, supported by digital and physical platforms.

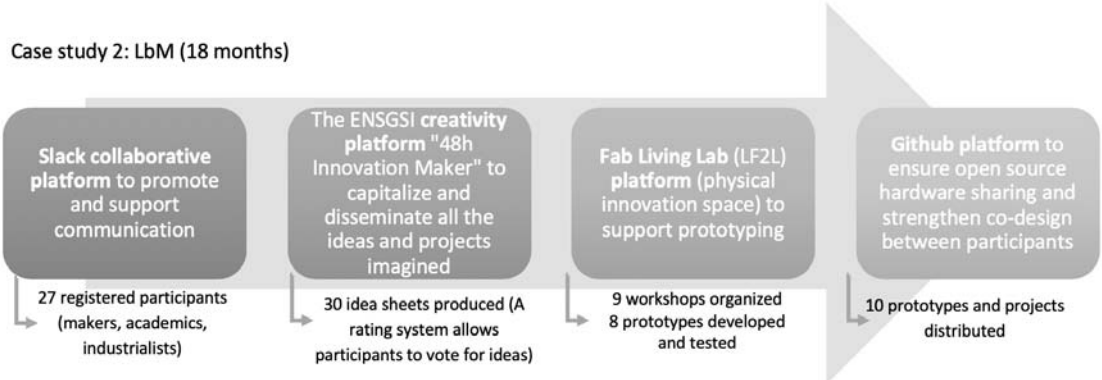


Figure 19. Sequential vision of the complementarity of the support platforms for co-creation within the LbM projects, adapted from (Dupont et al., 2017)

LbM's main challenge is to get actors from different parts of France to collaborate with each other, with different timeframes (full-time and/or occasional contribution, paid or voluntary, etc.), different practices, etc. In other words, it is a question of articulating four dimensions (Dupont *et al.*, 2017): (1) ***Geography*** with FLRs in four different regions, themselves composed of actors distributed throughout their territory, leading to a lack of face-to-face interactions (lack of spontaneity); (2) ***Conceptual*** because the terms "creativity", "energy" and "open source/hardware" do not refer to the same representations and uses according to the actors; moreover, the project started with an approach to creativity (i.e. producing abstract concepts with an academic method) while the makers are in the "make" (disassemble, reassemble, reproduce, transform, etc.); finally, LbM brought together and confronted structured organizations and very agile or fuzzy organizations with sometimes contradictory governance modes; (3) ***Technology*** with a strong initial limit – the distributor did not want to lend smart meters and the participants had no in-depth technical knowledge of this technology or of other aspects of the project (measuring electricity, developing objects in open hardware, working in open source, etc.); (4) ***Time***, which is expressed in terms of the time available to participants according to whether they can invest themselves over six months, two years, the time of a weekend, etc. Time also concerns the management of the knowledge produced: how to leave contributions that others can take up and enhance?

Beyond these four barriers to be overcome to ensure collaboration, this case study highlights three observations related to the process of identifying and co-creating the uses of electricity distributed by smart grid: (1) Each has its own practices and objectives: an "engineering" company with an industrial strategy, academics with a research project, FabLabs with their specific history, logic of action and different interests, etc. (2) The makers (at the time of the LbM project) are ultimately not very interested in or accustomed to energy issues; moreover, it is necessary to learn to give concrete expression to intangible elements (energy, electricity, trust, data, communication etc.). (3) The integration of users in the product launch phase, when irreversible strategic decisions have been taken, is too late, which inhibits self-determination and the motivation to be part of a co-creation process. It is a question of co-constructing a vision shared by all the actors in the upstream phase.

Like the Swiss ELL context, the French context has largely conditioned the predispositions of the actors to collaborate, requiring the transcendence of individual and specific practices and centres of interest strongly rooted in each other to build a community of interest in a vague and tense context (Assemblée Nationale, 2016).

Finally, we can summarize the management of the LbM project in 5 challenges that had to be overcome to create a favourable climate of collaboration between the actors: (1) Having a common representation of the project; (2) Ensuring interactions between communities at the right time in a process under construction; (3) Developing governance compatibilities through peer-to-peer negotiation; (4) Managing internal and external communication; (5) Giving a concrete explanation to intangible elements and using different media to materialize both the project process and its outputs. By proceeding in an iterative and constructivist manner, the research team, in interaction with the participants, deployed and accompanied or adapted the use of the following collaborative technologies.

We are aware of the non-exhaustive nature of the approach to be taken, particularly with regard to energy transition issues. The work of Koirala *et al.* (2018) highlights in particular the importance of local communities for involving citizens and users in the development of new responses such as community energy systems. This study also shows that trust in the local community is one of the key factors for engagement.

4.4 Towards a support system for trust in the co-creation of value

4.4.1 Findings from the two case studies

The two experiments we have carried out and studied allow us to highlight the challenges related to building stakeholder confidence and trust at the different levels of a Living Lab project. Beyond the limitations encountered in the implementation of projects, their observation and analysis give us the opportunity to better understand the mechanisms in place between communities that are distributed and solicited to contribute to a common project. The researchers' commitment to the design, installation and activation of the processes and the extensive nature of the analyses we were able to produce from these two projects, 24 and 18 months respectively, allow us to access both a quantitative and qualitative reading of these original research materials. Figures 18 and 19 thus present the main technological elements deployed to support co-design in ELL and LbM projects and foster trust between stakeholders. The physical or virtual platforms mobilized are classified in order of appearance in the process of each project. These diagrams also indicate the quantitative productions resulting from each of them.

Based on the observations and analyses reported in the section dedicated to research design, we can improve each of these processes in order to strengthen co-creation of value between the actors (Figure 20). It appears that two functions are not yet fulfilled by any of the projects: the appropriation within companies of ideas generated outside and the ability to retain and engage consumers or communities in a co-design process involving a company. In both cases, it should also be pointed out that academics have probably played a role as trusted third parties in the process and in the issues submitted to users. The proposal to support service design conceived by ELL can be assimilated to the practice of LF2L and implemented for the LbM project, and finally, the prospect of the emergence of a platform connecting buildings, consumers and producers is specific to the French case, and therefore not yet generalizable.

For each platform and technology used during the co-design process, it is necessary to consider the trust that users place in them, as well as the role that these technologies play in the level of trust that stakeholders place in each other. How does the integration and implementation of these technologies generate a favourable climate among stakeholders to build mutual trust and collaborate together? In other words, by drawing on the elements of the literature relating to trust (West, 1990; Mayer *et al.,* 1995), how to ensure that these technologies encourage an innovative climate within an Open Innovation process involving users: (1) benevolence; (2) the ability to fulfil the “obligations” agreed upon between the parties; (3) sharing and adhering to clear and valued objectives; (4) the emergence of a non-threatening environment where the parties can contribute and influence decisions by being recognized and valued in their contribution; (5) the pursuit of excellence through quality work and critical evaluation; (6) the enhancement of innovation and support for working practices to achieve innovation.

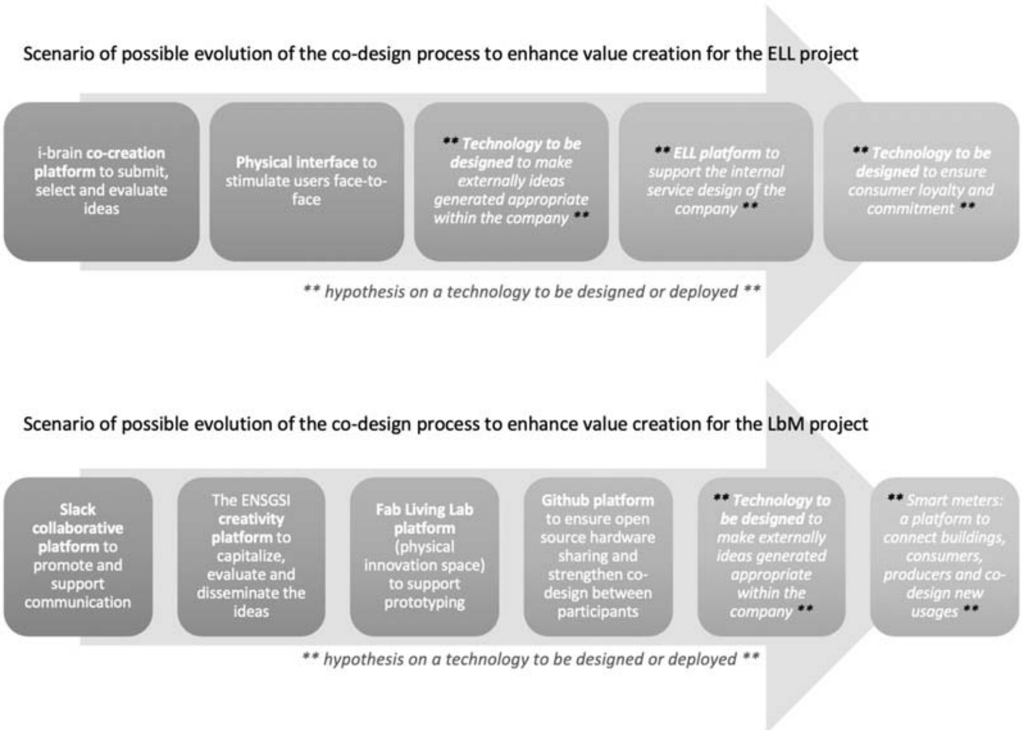


Figure 20. **Proposed evolution of technological supports to strengthen co-creation of value for each of the ELL and LbM projects**

4.4.2 Outline of an integrated process for co-creation of value

In the light of the previous findings, we can outline a process with new technological responses. Figure 21 below thus proposes an integrated vision of good practices to establish a climate of trust between the stakeholders in a Living Lab process. This potential process is built by aggregating and scheduling the various data and feedbacks from the two case studies. We have identified eight main functions (Figure 21) that a Living Lab must perform to strengthen the trust in a co-design process: (a) Communication, defined by “to promote and support physical and virtual communication”; (b) Ideation defined by “to submit, select and evaluate ideas”; (c)

Materialization defined by "to support collaborative prototyping of products and services"; (d) Contribution defined by "to ensure the sharing of co-creations in open source hardware"; (e) Appropriation defined by "to make externally generated ideas appropriate within companies"; (f) Validation defined by "capitalize on tests by use (and feedback)"; (g) Compensation defined by "to engage communities and make them loyal"; (h) Publication defined by "to guarantee transparency". The definitions we use for these functions come from the cases studied and our experience in the field of project co-design as a project manager for 15 years. The sequential presentation of functions follows the order of occurrence observed in the practical cases, without freezing these steps, which can sometimes be carried out concurrently. Feedback loops, or at least iterations, should also be considered.

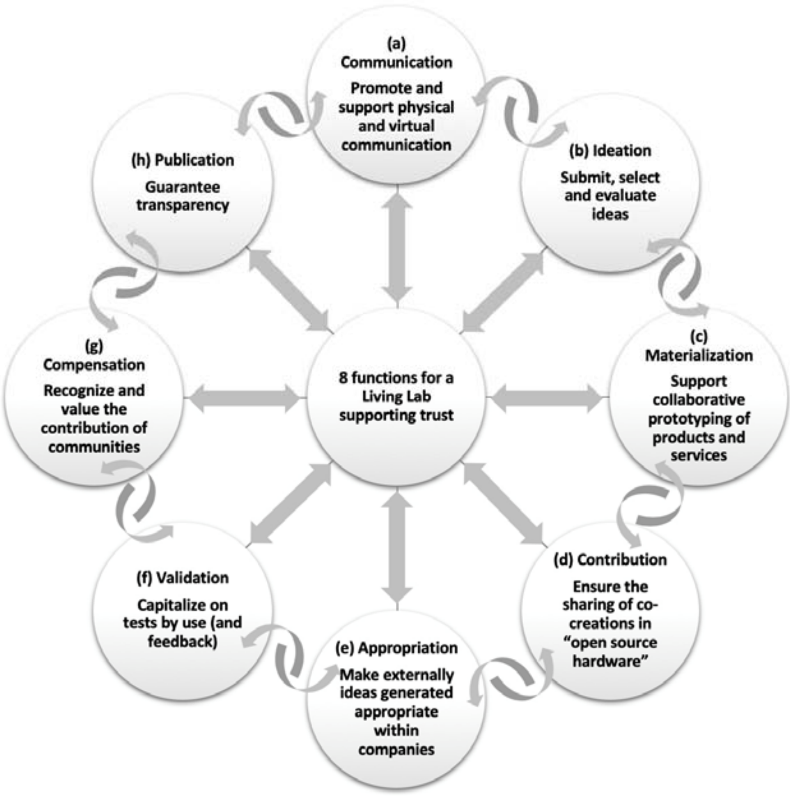
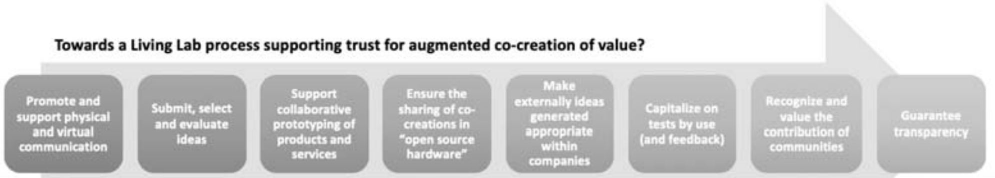


Figure 21. Eight main functions for a Living Lab supporting trust

To characterize and refine the eight functions that a Living Lab must perform, we have crossed them with the determinants of trust from literature within a co-design process including users. This method allows us to sketch a matrix, called "Co-coon" (for co-creation, confidence and trust), which we have completed from the work presented in the previous sections. The content of the matrix constitutes exploration work for researchers and practitioners as a guide to good practices and possible avenues for implementation.



Functions / Trust (adapted from West 90; Mayer et al. 95)	(a) Communication	(b) Ideation	(c) Materialization	(d) Contribution	(e) Appropriation	(f) Validation	(g) Compensation	(h) Publication
(1) Benevolence	Within and between communities C1 – C2	Let the actors express their ideas C1 – C2	Give implementation to a third party C1 – C2	Let others modify your idea C2	Value external ideas and agile methods to include the customer NE	Guarantee the right to make mistakes for yourself and others NE	Identify all the contributors C1 – C2	Allow anonymity C1
(2) Ability of the parties to fulfil their obligations	Increase awareness of your skills C2	Support or seek conceptual skills C2	Support or seek prototyping skills C2	Support or seek computer skills C2	Develop a corporate culture NE	Share evaluation criteria C1 – C2	Share the capital gains NE	Be aware of your abilities and prove them C1 – C2
(3) Sharing clear and appreciated objectives	Describe the framework for each C1 – C2	Specify the selection procedures C1 – C2	Show progress towards objectives C1 – C2	Expose and share the 1st results of the co-creation C2	Bring communities together C1 – C2	Commit to objectives and adapt them if necessary C1 – C2	Listen to needs C1 – C2	Respect the objectives or explain drifts C1 – C2
(4) Non-threatening environment to contribute and influence decisions	Dispel misunderstandings C1 – C2	Expression of divergence C1 – C2	Materialise to guide the choice C2	Enable co-construction C2	Encourage collective and team spirit C1 – C2	Share decision criteria NE	Reward the contribution C2	Keep a record and be able to consult it C1 – C2
(5) Achieving excellence through quality work and critical evaluation	Encourage listening and interaction C1 – C2	Deepen and compare ideas C1 – C2	Confront ideas with their feasibility NE	Seek improvements through the collective C2	Accept constructive criticism C1 – C2	Confront ideas with usage NE	Ethics of compensation NE	Evaluate the impact and terms of sustainable development NE
(6) Valuing innovation and supporting practices	Multiply the modes of communication C1 – C2	Encourage the submission of ideas by teams C2	Rely on innovation spaces C2	Develop "smart contracts" NE	Disseminate the innovation process NE	Share feedback C1 – C2	Towards shared properties NE	Engage in a prospective approach NE

C1: observed in ELL – C2: observed in LbM – NE: Hypothesis from the Literature but Not Experimented Here

Figure 22. Co-coon Matrix to strengthen co-creation, confidence and trust in a Living Lab process

In concrete terms, the Co-Coon matrix, based on the analysis of the literature and our case studies, proposes possible actions at each stage of the process to strengthen trust. Each box is a sub-process of co-creation of value reinforcing one of the six properties and performing one of the eight functions. Our multiple-case study generated data for thirty-five cells. For example, box (1-d) comes from an LbM project where the Github platform allows you to modify or enrich individual production; (5-a) underlines that a mediator has to dispel misunderstandings. Thirteen (grey) boxes are filled with data from literature and professional experiences. In 1-d, literature suggests to use agile methods popularized by the notion of agility in the IT field (Highsmith and Fowler, 2001). Agility is available at different scales, from the small team within a company to complete organizations, whether industrial or public. For example, (Dikert, Paasivaara and Lassenius, 2016) specifically study agile transformations at the level of large industrial scales. (Mergel, 2016) focuses its work on governments.

5. Limits

These works are pioneering in two ways: in terms of Living Lab, trust, and co-creation of value, through an original reading of literature and a linking of concepts; in terms of field of observation and implementation because the energy sector is currently undergoing change. In this paper, we assume the iterations and exploratory logic between the action-research of researchers engaged in Living Lab projects on energy and a more classical state of the art work. The involvement in our long-term projects enabled us to identify and validate the research gaps. We were also able to build a first project management model. Nevertheless, it is now necessary to test and validate or improve the Co-Coon matrix by building new projects applied to the consumer energy market and other topics. It could also be relevant to measure the creation of potential value for each box or to assess the risk of destruction of potential value in the event of non-implementation. New resources are therefore needed to engage many actors in such an approach over a long period of time.

6. Conclusion and prospects

In this article, we have recalled the fundamental aspect of developing trust within innovation processes to guarantee and amplify their open character and strengthen users' involvement. Nevertheless, the literature highlights the lack of research to understand and accurately characterize the mechanisms underlying the establishment of shared trust in collaborative processes, such as co-design. Two case studies based on a greater consideration of users in the field of energy distribution and management allow us to illustrate and highlight some of the determinants of trust for the co-creation of value. This longitudinal study on projects that took place between January 2014 and July 2017 would need to be supported by the exploration of new data from specifically oriented work on this subject. Putting the user or consumer at the centre of an innovation process and at the heart of service development, for example, does not guarantee their loyalty and commitment. On this point, seeking to test the statistical correlation between the implementation of co-design process methods and the appropriation of the services thus developed by users would legitimize this approach. Because, as Gassmann and his colleagues observe (Gassmann *et al.,* 2010), there is a lack of measurement of the effectiveness of this process. It would also be relevant to conduct research in other industrial fields to validate

the generic dimension of the proposed model to support the co-design process (Figure 22). We have deliberately not integrated the technologies of the smart meter into the latter. These make it possible to collect usage data in near-real time, opening up new perspectives in the relationship with the user and the development of service offers for customers. The creation of these data by users, their collection and use is the subject of a democratic debate in France (Assemblée Nationale, 2016). The controversies in several European countries about smart meters also underline a certain distrust of these newly deployed technologies.
Moreover, the recent *a priori* diffusion of the OI paradigm in the energy sector (Greco *et al.,* 2017) may generate different practices from industrial sectors already largely engaged in this logic. A comparative approach would undoubtedly strengthen the Co-coon Matrix we are proposing. Finally, the intangible, even abstract, nature of energy and electricity seems to make it difficult to mobilize neophyte actors with low energy literacy on issues that can quickly become technical or at least require the assistance of specialists to shed light on particular points. A greater effort in communication, vocabulary creation and shared representations seems necessary to overcome this difficulty. The development and use of innovation spaces that bring stakeholders together and collaborate could provide a favourable framework for the emergence of collective intelligence (Morel *et al.,* 2018) in the service of projects and ecosystems. To enhance the efficiency of our model, the time dimension will also need to be studied. Indeed, our two case studies describe projects that span almost two years. Is it a constant or a contest of circumstance? Minimum durations should be measured to ensure the success of each step of the Co-coon Matrix – and to evaluate how the industrial domain concerned, the diffusion of open innovation, and societal engagement influence the temporality of the process.

More generally, all the elements of the Co-coon Matrix can be the subject of an experimental program to consolidate and enrich this first proposal with a better consideration of trust in co-design processes. In addition, Co-coon Matrix proposes functional building blocks from a multitude of physical and virtual platforms. Based on this model, it would be interesting to study the possibility of deploying a digital technology that integrates all these functionalities and that would be the "digital twin" of a physical platform dedicated to collaborative innovation, generating a framework where the appetite for creativity is truly released. The recent emergence of the blockchain (Nakamoto, 2009) in support of the decentralized system of trust seems to offer new perspectives in many fields, such as democracy (Caseau and Soudoplatoff, 2016) and manufacturing. This technology also seems to provide specific answers to the challenges of co-creation of value (Seulliet, 2016; Duvaut *et al.,* 2018). Technological building blocks combined with a relevant organizational model could therefore offer a climate of trust in the communities of co-designers and give meaning and motivation to the actors involved in OI processes.

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Chapter 5

Energy management in a public building: A case study co-designing the building energy management system

In 2017, the Energy Living Lab continues to evolve and standardise its co-design processes. The following article is part of another project, "Bellevue", with the aim of co-designing and producing a Building Energy Management System to optimize energy conservation. From a crowdsourcing process involving a company and its customers in Chapter 4, this paper presents a process involving numerous stakeholders in an ecosystem of actors. The increased complexity of the orchestration requires a well-structured process.

This fifth chapter will be composed of a case study using the Energy Living Lab method to integrate all the stakeholders and not just the consumers to co-design a building energy management system. This corresponds to the "concept phase" of the open innovation process to co-design an energy conservation intervention. This applied research paper was presented at the international IEEE conference "ICE" in Madeira in 2017[16], a pluridisciplinary conference bringing together engineers, architects and business scholars.

[16] Draft version before publication

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Abstract

Buildings are important contributors to energy consumption accounting for around one-third of energy consumed in cities, where large public buildings are the dominant energy consumers. Accordingly, building energy management system (BEMS) can be defined as a system with combination of both intelligent and green building technology (Ma & al, 2010). Previous literature has already presented a set of technical features of a BEMS. Therefore, in this paper, we shall focus on stakeholders of a BEMS and we aim at understanding how to engage and empower them in order to design a system that fits the needs of the different sub-groups in public buildings. We have tested the Living Lab method to co-design the BEMS, with a case study in a large public building. The main findings can be summarized as follow: the implication of all the stakeholders since the beginning is crucial to reduce failure risks. The establishment of a steering committee empowers key stakeholders to improve the BEMS. Information given by smart-meters installed to monitor energy consumption has to be transformed into actionable indicators to be helpful for the building service maintenance. Automatic advices based on algorithm should be proposed as, even though they might be more expensive. The proposed method offers a relevant contribution to the existing body of knowledge, as it allows BEMS designers to integrate the relevant stakeholders in the co-design of the system and describes how to proceed. In the future, we intend to apply our approach to other public buildings to further improve and validate the method.

Keywords: Building energy management system, co-design, living lab, socio-technical systems.

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5.1 Introduction

Buildings consume approximately one third of the total primary energy in the world. Switzerland is not an exception with 40% of total energy consumption attributed to buildings.[18] One of the main objectives of the Swiss Energy Strategy 2050 is to increase energy efficiency in the building sector (SFOE, 2017). The Swiss energy strategy imposes as well to public sector to be exemplary.

A well-studied set of infrastructure measures can be taken by the managers of public buildings to increase energy efficiency with respect to heating, lightning, air conditioning, etc. Optimized control systems are also an opportunity to increase energy efficiency without compromising the overall comfort. The collected data on energy consumption and production can be monitored in real-time by installing smart meters in the building. These data can be used to detect problems with existing facilities and can be carefully analyzed to identify potential of energy conservation.

An extensive meta-analysis of the different optimized control system is proposed by Shaikh and his colleagues (2014). They have reviewed 121 works on the thematic. In the meta-analysis of Shaikh on building energy management systems (BEMS), they reviewed the principal technical methods to ensure the indoor building comforts (thermal, humidity, indoor air quality and illumination levels) in order to have a perfect balance between occupants' preferences and electrical energy control and saving. They propose three important levels in designing a BEMS: (1) Building control system (BCS), (2) computational optimisation methods and (3) simulation tools.

(1) BCS can be separated in two subcategories: conventional and intelligent systems. Both are linked to a monitoring and a control of the system. The most common are the model based on predictive control, which are very interesting because they use, as an entry data for the model, weather forecasts as well as human behaviour.
(2) Computational optimisation methods: optimisation is needed generally to minimise (cost and energy consumption) or to maximise comfort. Genetic algorithms (GA) are the most used.

[18] http://www.bfe.admin.ch/energiestrategie2050

(3) Simulation tools: complement the optimisation approach. Matlab in the survey as the most common program for this solution.

Authors conclude that an extensive number of studies on automate controls system and computational optimisation strategies have been implemented, but they also indicate a gap in the understanding of the human part nourishing the system: "building occupants' behaviour, activities and preferences are the most important feedback for smooth building automation." This aspect needs further researches to understand the role of the occupants on the BEMS.

In the design of the BEMS, the integration of all the stakeholders and not only the occupants could be one of the key factors to consider different needs and expectations. The main objective of this study is to develop and test the Living Lab method as a way to co-design a BEMS. By integrating all the key stakeholders at an early stage of the design process, the idea is to develop an efficient and proactive energy management system for a public building.

Our research question is defined as follow: **How to involve the different stakeholders in the design phase of the BEMS? What would be the impact of their involvement on the design?**

In this paper, firstly we will present the main literature streams related to Building Energy Management Systems, Co-creation and Living Labs. Then we will introduce the methodology and the case study in a public building. Finally, we conclude by expressing the limits and further researches.

5.2 Literature review

5.2.1 Building energy management systems

Building Energy Management Systems (BEMS) is a decision support model optimizing quality of living for the occupants and energy conservation in the building. The system should contain intelligence and detect the deviance to the set standard values. Different sources of data can be collected through indoor and outdoor sensors (temperature, air quality, humidity, movement, luminance…) (Doukas & al, 2007).

The energy management in a public building is different from the energy management of a private house because occupants of public building have not the ability to take decision about energy management (Weber, 2000). As mentioned by Saele et al. (2005) in public companies the decision-making process about energy project is slower than in private companies because they depend on political decisions on supervisory level and have to be validated by different departments before being realized. According to Cooremans, the strategic nature of project is the main criteria of investment choices (2010). Projects linked to energy efficiency are perceived as moderately strategic by managers of tertiary sector. Energy costs are perceived as small by financial managers of companies and the perspective of energy cost reduction isn't a motivation for decision making.

On the contrary, Saele et al. affirm that both in the literature and among policymaker, cost savings is the most important factor when evaluating energy efficiency actions because public entities have to stay within the allocated budget (2005). This budget which sometime encourages companies to reduce their energy consumption could have a perverse effect: due to limited budget, companies don't take the risk to invest in energy saving measure. In addition, Harris et al. affirms that the main criterion used by companies concerning energy efficiency measure is the payback period (2000). The higher are the costs of an energy efficient measure, the more reluctant are the managers to implement this measure. Hence the development of energy performance contracts in which ESCO finance energy efficiency investments and is partly remunerated on the energy performance gains. From Weber perspective, directors generally invest in energy efficiency only if it is highly profitable because they want to concentrate themselves on the core business of their company (2000).

What is the first step to analyze the potential of energy conservation in a public building? To monitor the current energy consumption. According to Yu et al, managers have to collect seven types of data: (1) climate, (2) building-related characteristics, (3) user-related characteristics, (4) building services systems and operation (5) building occupants 'behavior and activities, (6) social and economic factors, (7) indoor environmental quality (2011). These authors affirm that "in order to obtain the full effects of user behavior, one possible approach is to extract corresponding useful information from real measured data, since such data already contains the full effects ».

5.2.2 Socio-technical systems

The Smart meter permits to monitor and collect automatically the energy consumption of a building and to make it visible. Indeed, smart meter allows to transform (or they should allow to transform) the monthly energy bills which are rigid and not understandable into real time, transparent and controllable indicators (Ahmad et al., 2010).

To enable reduction of energy consumption, consumers need feedbacks from smart meter (Darby, 2006). It allows them to visualize the effects of their efforts on energy consumption, costs and environment (Paetz et al., 2011). In their study, Ahmad et al. show that instantaneous feedbacks permit to reduce energy consumption by encouraging consumers to realize a more efficient usage of their resources (2010).

Concerning the type of feedbacks, the vast majority of authors agree that indicators must be clear, simple and comprehensive by consumers. The consumers wish to have detailed information in real time (Paetz et al., 2011). For example, kWh and carbon dioxide aren't good indicators because most of consumers don't know the meaning of these indicators (Wilhite and Ling, 1995). The consumers also indicated that they would like to compare their energy consumption with other consumers, during the whole year (Darby, 2006).

The monetary indicators are generally qualified as good because consumers can easily understand them. In addition, the main motivation to use smart meter is the financial saving realized and on a second plan reducing the environmental impact (Paetz et al., 2011). In contrast, Darby brings to light that one of the key factors of success for reduction of energy consumption over a long period are personal motivations of consumers and not the saving they can achieve (2006).

In conclusion, energy management systems in buildings are managed by people with different sensitivity and behavior related to energy consumption. These elements have to be considered when designing a BEMS.

5.2.3 User driven open innovation

Open Innovation approach has emerged in year 2006 with the first book on the theme, *Open Innovation: The New Imperative for Creating and Profiting from Technology* written by William Chesbrough. This theory results from a common problem observed since 2003: companies did not innovate as they should in order to insure a dynamic and attractive economic fabric. Thus, open innovation approach tends to improve this lack of performance by promoting the use of internal and external ideas to create value, as well as internal and external ways to reach new or existing markets. Baldwin & von Hippel have clarified the terminology and stated that innovation was considered to be “open” when findings become a public good, which is not retained within the closed boundaries of a company or any organizations (2011).

If these boundaries are deleted, the system allows inputs of numerous other actors, which include the end users. This new way of considering innovation processes is very different from the traditional manufacturer-centric model, in which companies develop products and services in a closed environment, with the fear of potential copies or imitation (Von Hippel, 2005).

Customers and consumers could be involved in the innovation process and become co-designers. This approach encourages them to share and build on other’s people ideas and to imagine the ideal product or service that will respond to their expectations; this innovation process becomes “user-centered” by suppressing the intermediaries and promoting direct interactions between companies and customers (Von Hippel, 2005). The main observed advantages involving users early in the development process are (1) the reduction of the failure rate at the market and (2) the user-acceptance increase of new products, services or processes (Bilgram et al., 2008).

With the aim of involving users and other actors that stays usually outside the company's well-defined environment, the Living Lab method seems to be a relevant approach in order to promote open-innovation and co-creation of value among different stakeholders.

5.2.4 Living labs

According to Pallot and his fellow researchers, working on the Living Lab thematic: “a Living Lab is an open research and innovation ecosystem involving user communities (application pull), solution developers (technology push), research labs, local authorities and policy makers as well as investors.” (2011). The European Network of Living Labs (ENoLL), founded in 2006, have added a characteristic in the previous definition. In a recent paper ENoLL explains that Living Labs usually tend to integrate research and innovation processes in real life communities and settings (ENoLL, 2015).

Therefore, the Living Lab innovation process counts on the openness, the diversity of actors, the multidisciplinary vision and the multiculturalism in order to generate innovative and disruptive ideas thanks to the power of the collective intelligence framed in an environment that provides structure and governance to participants (Almiral and Wareham, 2011). To deepen the analysis, Schuurman proposes to separate the LLs methodology in three different levels: A macro level, a meso level and finally a micro level (2015). As this paper will focus more on the reunification of different stakeholders to make them collaborate, it seems relevant to explain the macro level as defined in previous papers.

According to Westerlund & Leminen (2011), living labs are: "physical regions or virtual realities, or interaction spaces, in which stakeholders form public-private-people partnerships (4Ps) of companies, public agencies, universities, users, and other stakeholders, all collaborating for creation, prototyping, validating, and testing of new technologies, services, products, and systems in real-life contexts". These public-private-people partnerships underscored by the two authors has been progressively transformed and arranged in a new model called "The Quadruple Helix model". This model now includes four "helix", the academy, the industry, the government and the public. The last term, placed in this context, includes all aspects related to the civil-society, culture, values and lifestyles, creativity, media, art, etc. (Carayannis and Campbell, 2011). Thus, researchers wanted to test a Living Lab applied research method in order to co-design a BEMS.

5.3 Methodology

The paper is based on a single case study in a public building. Yin (2013) proposes a systematic process to ensure rigorous research design, data collection and analysis. "Why" and "how" questions encourage the use of the case study method. The goal is not to generalize the results of this case study. The procedure is described below in order to be able to replicate it.

In a Living Lab setting, we propose a co-design method composed of five steps: (1) Identification of stakeholders, (2) Pre-analysis of stakeholders (3) Face-to-face qualitative semi-directed interviews, (4) Workshop to co-design the BEMS, (5) Pilot of the BEMS in the building.

5.3.1 Identification of key stakeholders

The aim is to identify and select the main stakeholders with an interest and an impact on the BEMS of the building. The quadruple helix model encourages searching for four sub-groups: (1) public entities, (2) private companies, (3) academics, (4) users of the BEMS. John Bryson (2004) proposes in his article "What to do when stakeholders matter", different methods to identify and analyze stakeholders.

5.3.2 Pre-analysis of key stakeholder

We have selected from Bryson (2004) the power versus interest matrix developed by Eden and Ackermann (1998) for its simplicity of use and its capacity to priories the different actors. The graphical representation is visual and allows classifying stakeholders in four categories: (1) Players (+Power, +Interest), (2) Subjects (-Power, +Interest), (3) Context Setter (+Power, -Interest), (4) Crowd (-Power, -Interest).

This matrix allowed proposing hypotheses on the level of power and interest of each individual actor related to the BEMS before the primary data collection. During the interviews, it is then important to collect the perceptions of the different stakeholder's categories about the self-determined level of power and interest regarding the BEMS. The proposed hypotheses (based on secondary data) will then be confronted to the interviews (primary data). Inferences are proposed when discrepancies appear between the hypotheses of the research team and the self-determined level of power and interest by the stakeholders. The matrix permits to better understand the decision process in the analyzed ecosystem.

5.3.3 Face-to-face qualitative semi-directed interviews

What are the perceptions of the stakeholders regarding the BEMS? A thematic semi-structured interview guide has been developed. This guide allows having a common thread for the interviews with stakeholders. The objective of these interviews is to identify interests and measures which can influence the project. With this method, we would like to understand stakeholders' motivations, misgivings, needs and expectations in the actual energy management system for the building. We interviewed the selected key stakeholders identified in the matrix with the same interview guide. All the interviews were recorded on a numeric audio format and at the end of each interview a detailed report was transcripted and coded by the surveyor.

5.3.4 Workshop with the stakeholders

Shortly after the interviews, a workshop is organized with the aim to expose the results to the stakeholders and to involve them in the improvement of the energy management system. A prototype of the system is co-designed with the ecosystem of actors. During the workshop it is important to give the voice to every participant and to moderate the discussion.

5.3.5 Pilot of the BEMS in the building

At the end of the workshop, the developers of the BEMS modify the prototype to take into account the input from the different stakeholders. They will then run a pilot of the BEMS in the building, involving the stakeholders. With an agile method, they will continuously improve the prototype to fit the different needs of the stakeholders until the system is satisfying. The focus is on the personalization of the solutions.

5.4 Case study

5.4.1 Context

This article is based on a case study and was realized in the building « Bellevue » owned by the University of Applied Sciences Western Switzerland. Built in 2001, this building was one of the first low consumption buildings labeled "Minergie" in Switzerland (www.minergie.ch). The School of Management and Tourism and the School of Social Work are located in this building.

The main users of the building are students, teachers and the administration team, representing more than 1'000 students, 200 employees and 40 classrooms.

In the framework of the applied research project, the building was recently equipped with smart meters collecting electricity, heating, hot water and gas consumption. On the roof of the building, solar collectors for hot water have been installed. The Minergie label imposes the production of renewable energy in the building. Before the construction, the architects decided to include solar collectors to meet this requirement. Unfortunately, the university consumes little hot water and only in the cafeteria, causing system overheating problems. After ten years, the thermal panels will be replaced by photovoltaic panels. Their production is also monitored. The electricity consumption is measured each 15 minutes. It appears, from the first data analyzed, that the energy performance is not optimal. For instance, the building consumes a high quantity of energy during the week-end, even when it is empty.

Hypotheses were formulated on the use of the building to calculate the Ex-Ante consumption forecast. One of the hypotheses was that the classrooms would not be used more than eight hours per day. In the last decade, the students' effective increased each year and the classrooms where used almost 100 % and more than eight hours a day. The building is not equipped, in term of ventilation for instance, for such an intense use.

In addition to the consumption's measures, the thermal and visual comfort and plug loads are also monitored. The ventilation and the heating can be followed each day. For the visual comfort in the classrooms, they are artificial lighting and solar radiation blinds which can be controlled. In a business school, the students use their own portable computers and charge them regularly when at school.

5.4.2 Decision process

On the organizational level, the University of Applied Science Western Switzerland located in Wallis is administrated by a management team with five departments: (1) infrastructure, (2) communication, (3) IT, (4) finance and (6) human resources. In addition, each high school has its own director. The management board is a matrix composed of the responsible of each department, the directors of each faculty and the director of the university. The decision process is complex for a BEMS that involves all the departments and faculties.

To complicate the process, the building "Bellevue" does not belong to the university but to the State of Valais. It is managed by two janitors under the supervision of the responsible of the infrastructure department. In financial terms, the energy consumption represents less than 1% of the total yearly budget. It is not an important cost item for the school.

5.4.3 Managerial questions

This applied research begins with a managerial question: why a BEMS is a necessity in the building? What are the priorities of the management when implementing such a system in the future?

The director of the School of Management, when face-to-face interviewed, mentioned five priorities for the BEMS: (1) detecting failures: the heating system as well as the ventilation do not work properly. Complaints from the students and from the janitors are reported on a regular basis. (2) Justify investments: a BEMS could provide data on hidden costs of the failure and necessity to invest to correct the failure. (3) Exemplarity: public buildings and a fortiori schools have an exemplarity role to play in the Energy Strategy 2050 decided by the Swiss government. (4) Energy efficiency: the building consumes more than what it was supposed to, and the performance gap needs to be reduced by technical as well as human actions. (5) Education: an Energy Management course is proposed as an option for the economists and engineers. The development of the BEMS could be a teaching support for engineers and economists.

5.5 Findings

5.5.1 Identification of stakeholders

As explained in the methodology, a list of stakeholders related to the BEMS has been proposed. Depending on their function, we assume that they have different needs and expectations concerning BEMS. We have selected the following stakeholders: (1) Head of School of Management, (2) Head of Business Information System Program, (3) Head of Infrastructure Department, (4) Head of IT Department, (5) Professors, (6) Responsible of the Executive Program "Quality Management", (7) Responsible of the consecutive Program "Energy

Management”, (8) Janitors, (9) Responsible of the cafeteria, (10) Responsible of the energy and installation of the State of Valais and (11) Students.

5.5.2 Power versus interest matrix

Before organizing semi-directed qualitative interviews, we have analyzed the initial situation, as we perceived it from an academic point of view, based on a desk research. We would then interview the main stakeholders and compare our initial hypotheses on the level of power and interest of each actor with the self-perceived level of power and interest. The occupants of the building (students, professors, administrative employees) were considered as having low power and low interest related to the system of management and have not been interviewed. It does not mean that they do not have interest in energy consumption of the building.

We have displayed the results of the pre-analysis in the Figure 23.

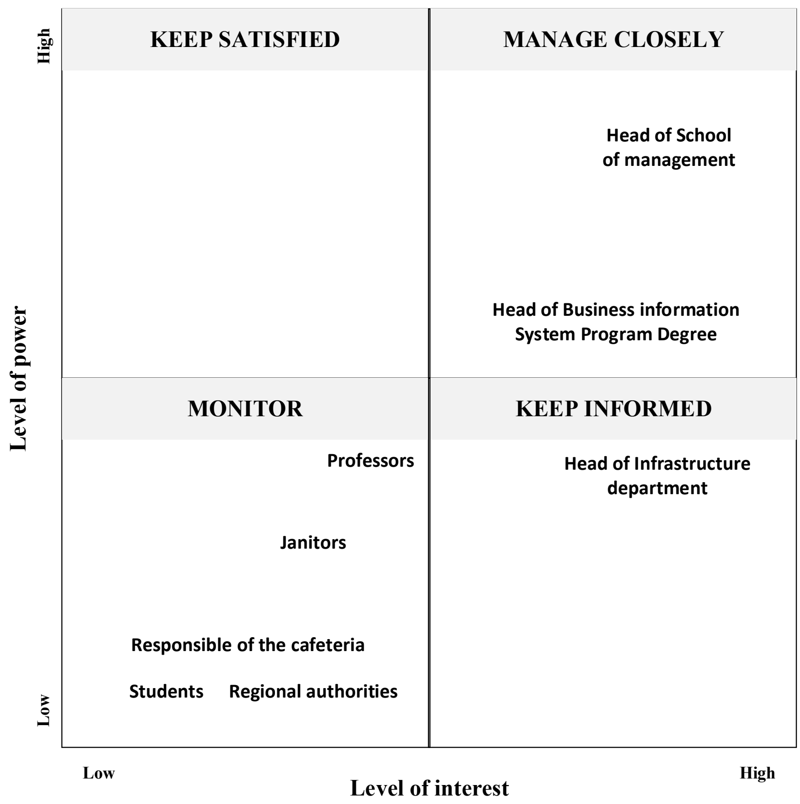

Figure 23. Power versus interest matrix (initial research hypotheses).

5.5.3 Perceived level of power and interest

In a second step, the power versus interest matrix was used to better understand the perceptions of the different actors. Two questions were asked, related to the perceived level of power to influence the building energy performance. Each stakeholder had to rate himself on a 0-10 scale. Stakeholders rated themselves high on interest related to the energy performance of the building, and low on self-power…

The only exception is the responsible of the cafeteria rating him 10/10 on power and motivation. He has set objectives for the energy consumption of the kitchen, he follows regularly key indicators to see if he is on track or not. For his cafeteria, he declares he is empowered to influence the energy consumption. It is not the case for the other parts of the building, namely the classrooms and offices, the conference aula. The director rates himself 1/10 on the power level at the moment and 10/10 on the motivation, focusing on the need to put in place the BEMS to feel empowered. His motivation is partly linked with problem solving: *"We know that there are issues, but had no element to know where it came from."* The heating system is not working properly and has been changed. The new one consumes more than the previous, explanation are needed. Perceived empowerment of the different actors seems critical for the launch and the exploitation of a BEMS.

5.5.4 Management objectives

In term of BEMS, projects often concentrate first on how to get the data on energy consumption and production and on how to analyze and then communicate the data, how to visualize it and act. Collecting and analyzing data is an important step regarding BEMS. But in this project, the research team wanted first to understand the objectives determined by the direction of the school and by the different actors in the system. Why is a BEMS deployed in the building? What are the strategic objectives to deploy it? Are the employees incentivized on the performance of the building?

The qualitative data indicate that no managerial objective is measured at the moment. The employees taking care of the maintenance and the investment in the building are neither measured nor incentivized on the energy performance of the building. Here is the director's view on the necessity of the BEMS: *"We need to see if the actions have an impact or not"*. It is not about why a BEMS is deployed but how are the data used to see the results of the energy efficiency actions for instance.

We have as well interviewed an expert in the field of quality management. He manages a strategic project on sustainable development in the School and confirms there is no objective for the BEMS or energy performance of the building. He agrees on the necessity of indicators, grouped on a dashboard to take managerial decisions. He adds*: "[Having objectives] is essential and must be part of a comprehensive policy for all staff members."* In term of granularity of information, he confirms it would be important to define beforehand the objectives of the BEMS.

The responsible of infrastructure indicates there is no objective regarding the BEMS or the energy performance of the building. But there is an infrastructure budget to take actions. The team proposed, for instance, to change the lighting system in the school. The responsible for the informatics adds: *"We do not need 36 indicators. We need total consumption and consumption of the different categories of devices. A temporal evolution and a sectoral analysis are also needed."* In other words, they ask for information to understand the drifts of energy consumption. It would be necessary to keep a detailed granulometry to analyze the drifts of particular equipment. This detailed information does not need to be visible to each stakeholder as "too much information kills information".

5.5.5 Building a common vision

At the end of the individual stakeholders' analysis and interviews, a co-design workshop was organized to co-develop the BEMS with them in the building "Bellevue". This workshop brought together all the stakeholders with the quadruple helix represented (Public-Private-People Partnership). Only two persons were not able to participate and one of them had a representative. The workshop enabled to build a common vision for the BEMS and to develop practical recommendations to reduce technical failure, increase comfort of users and decrease energy consumption of the building "Bellevue". All the stakeholders stressed the importance of improving the energy management system.

5.5.6 Co-design of an energy management plan

During the workshop, an energy management plan was developed and stakeholders publicly committed to take actions with this plan. The direction will set clear objectives of energy conservation and will measure them once a year with the energy dashboard and accountancy. The following action have been suggested: (1) establishment of a steering committee which meets twice a year and is empowered to act on the BEMS, (2) regulation of the heating system by professionals to avoid recurrent failures, (3) development of a BEMS which allows to centralize all the data of the building, not only on consumption but also on behavior and occupancy rate. The system should optimize the tradeoff between energy consumption and comfort of the occupants. (4) Students' awareness of the energy consumption in academic courses is also proposed.

5.5.7 Type of indicators

The granularity and complexity of information should be adapted to the needs of each stakeholder's group: "*Power consumption, lighting, laptops loading... This information is not important for everyone. For some people, it will not help. Indicators must be able to act with direct action and must be self-explanatory."* as reported by the responsible of informatics. *"Indicators should be tailored to the target audience."* adds the responsible of quality management projects. The information given by smart-meters installed to monitor energy consumption has to be transformed into actionable indicators to be helpful for the building service maintenance. From the director's perspective: *"The numbers have to be meaningful to make it work. KWh is useless because the person does not have a reference point."* As previously mentioned, they need to be actionable as well.

5.5.8 Frequency of feedback

The frequency of feedback needs to be adapted as well. Adaptation of a smart meter interface to allow real time visualization, personalized for each key stakeholder. Once a year is enough for the director to follow Key Performance Indexes (KPI) and decide on investments. He would like actionable information: "It needs to be a decision-making process." Once a month is enough for different responsible of departments. Once a week would be sufficient for the janitors under normal circumstances (from their point of view): "*There are weekly data collections every Monday morning. When we do it, we see immediately if there is a problem and we should make adjustments*" mentions the janitor. As soon as a failure appears, they would like to be informed with an SMS.

5.5.9 Automatic advices

Most of the time, people responsible for the maintenance of the building are not energy specialists. When the energy performance is not optimal, they do not know how to react and call a specialist. Sometimes, it takes a long time until the specialist is available and fixes the problem. The stakeholders have asked for an automatic advice embedded in the BEMS. The system should propose automatic advised based on algorithm even though they might be more expensive. At the moment, algorithm exists to detect failure automatically and inform the responsible. What does not exist is the algorithm to give automatic advices based on indicators, without been forced to contact a specialist when the building is underperforming. A new interdisciplinary team formed by part of the stakeholders decided to work on this automatic advice algorithm to solve this problem.

5.5.10 Crowdfunding to finance the BEMS

During this workshop, the possibility of crowdfunding the BEMS was proposed. It would allow the interested employees to co-finance the BEMS, making their investments profitable while caring about the impact of their work building on the environment. It may take the form of an energy performance contract for instance, with the remuneration directly linked to the performance of the building.

5.6 Conclusion

In an energy transition, imposed by climate issues, BEMS can play an important role, especially in existing buildings. To succeed in this project, especially in public buildings, users could be a source of reflection already in the design phase of the BEMS. The information must be "exploitable" by the receiver and the best way to do this is to co-design this information with the user. The tools designed by computer scientists must be adapted to the people to whom they are intended and this is even more important in BEMS as a complex socio-technic system, which combines a part of computing and part of technical installations. With this paper, we have contributed to demonstrate that the Living Lab approach could provide an effective method for achieving this goal. The case study method does not permit generalization. More tests are needed to replicate this method in different co-design contexts.

5.7 References of chapter 5

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Chapter 6

A conceptual model analysing building-in-use to act on energy performance gap

The last article if this thesis builds upon the findings of the preceding papers. The co-design process has been central in this thesis along with the social performance of energy services. This article proposes to focus on this concept and to propose a new theory of EPG.

This sixth chapter proposes a conceptual model to understand the energy performance gap. The model is induced from the previous studies and data collected. The notion of "social performance gap" will emerge as an important component that complements the economic and technical performance. This conceptual paper has been presented at the European Social Marketing conference in Antwerp in September 2018[19] and is published in the proceedings of the conference.

[19] Draft version before publication

A conceptual model analysing building-in-use to act on energy performance gap

Mastelic, J., (2018), *A Conceptual Model Analysing Building-in-Use to Act on Energy Performance Gap*, European Social Marketing Conference, Antwerp, September 2018.[20]

Abstract

The energy performance of residential buildings depends on a complex socio-technical system. There is often a gap between the planned (pre-occupancy) and the actual (post-occupancy) energy performance, which is not fully explained in the literature. What is the role of the "occupants" on energy performance gap? How to analyze the "social performance" of the system? The aim of this research is to make the link between engineering, economic and marketing theories to analyze this gap in residential low consumption "buildings-in-use" and to provide managerial implication to act upon it. Adding this understanding of the "social performance" in an integrated conceptual model is important in order to achieve the ambitious objectives of low consumption buildings. This theory building article is based on the existing literature and conceptual analysis. The new conceptual model takes into account the co-creation of value when the building is in use. We empirically illustrate the use of the theory with an innovative process combining Community Based Social Marketing and Living Lab methods. We will then test the impact on performance when co-designing an energy efficiency plan. We separate three types of energy performance gaps: (1) technical performance gap (2) economic performance gap (3) social performance gap. As practical implications, new indicators need to be developed to measure the "social performance gap" of buildings and the impact of value co-creation. The constructor should integrate all the stakeholders in co-designing new sustainable neighborhoods (feedforward) and in optimizing operation (feedback). As social implications, the inhabitants should be considered as co-creators of value to decrease the gap. The paper corresponds to the building of a new theory supported by empirical research. The proposed conceptual model has the advantage to take into account and integrate multi-stakeholders' perspective and to combine engineering, economic and marketing theories in one model.

Key words: co-design, living labs, energy performance gap, social marketing.

[20] Draft version before publication

6.1 Introduction/Background

6.1.1 Aims and objectives

The building sector contributes approximately to 40% of the final energy consumption and 36% of CO2 emissions in Europe and high policy goals have been set: "*by 31 December 2020, all new buildings are nearly zero-energy buildings"* (European Commission, 2013). There is often a discrepancy between what the building is supposed to consume in the design phase (pre-occupancy) and the actual consumption, in the operation phase (post-occupancy), even in low consumption buildings (de Wilde, 2014); this difference is named "**energy performance gap**" (EPG) (Jaffe & Stavins, 1994). The European Directive 2010/31 on energy performance of buildings is the main policy guiding national laws, which in turn influences the development of national architectural and engineering standards. Energy performance certificates are then based on the standards and communicated to the prospects to try influencing their housing choice. The EPG increases the risk of the certificate being perceived as "greenwashing" when the building does not deliver its promises. This could slow down the diffusion of low consumption buildings and technologies. The question of the overall research project is the following: "What would be the impact on EPG when involving the main stakeholders in the co-design of an energy efficiency (EE) plan in a sustainable neighborhood during the energy transition?" To answer this question, we need to understand first what is the role of the "social performance" of the energy services on EPG. Literature exists to define the gap, but the social perspective is not integrated in one theory. The aim of this paper is to provide a new conceptual model of EPG, combining theories from marketing, economics and engineering.

6.1.2 Behavioral objectives and target group

In order to define the objectives and target group, we need to explain the paradigm. The building is a socio-technical system (ST-System) composed of the interaction between techniques, human actors and rules (Geels, 2004). We aim to study the "building-in-use", thus the value co-created at the nexus of production and consumption (Skaržauskaitė, 2013). We take the viewpoint of Saunders et al: *"marketing is only one component of a complex, dynamic and evolving economic and social process»; «instead of concentrating on behavior* *change, the social marketer can focus on participatory social transformation*." (2015, p.8*).*" An attempt to change the unit of analysis from the individual behavior to the practice has been proposed with the social practice theory (Shove & Warde, 2002) cited by Hargraves and tested empirically in the environmental sector by this researcher (2011). Browne and her colleagues have used practice theory to segment water consumption and improve forecasting (2013). In this research, we will focus on heating practices to illustrate empirically our conceptual model. A pre-analysis in the sustainable neighborhood based on smart meter data and utility invoicing data indicated an energy consumption 30% higher than planned for heating. **We want to decrease by 10% the energy dedicated to heating the buildings in the neighborhood by the end of the next winter with constant or increased satisfaction and a ROI within 5 years.**

6.1.3 Target group

The main target group of this research is the "occupants": the inhabitants of a sustainable neighborhood under study (400 apartments) consuming energy services. As suggested by Heiskanen in a meta-analysis of 24 energy conservation interventions, *"the ability to engage diverse stakeholders and align their interests was a critical factor for success."* (2009, p.10). As we apply the Living Lab method (Liedtke et al., 2012; Schuurman, 2015), all the stakeholders will be integrated in an eco-system of actors to co-develop an EE plan in-context. A quadruple helix model is used for the classification and integration of the stakeholders (Arnkil et al, 2010): (1) **Academia/university**: one university and one university of applied sciences (2) **Industry/business**: building constructors, utility, smart meter providers, companies in the neighborhood, real estate agencies**,** (3) **State/government**: city authorities, federal office for energy (4) **Citizen**: inhabitants, association of inhabitants. They all contribute to the understanding of EPG with their own perspective. They will collaborate in situ to co-design the energy efficiency (EE) plan in an ecosystem of actors.

6.2 Method

6.2.1 Evidence of citizen/customer orientation

This theory building paper is based on a literature review and a case study. It follows four main steps: (1) Definition of variables, (2) Limiting the domain, (3) Relationship (model) building, (4) Theory prediction and empirical support (Wackers, 1998). To illustrate the theory, we will run an intervention in a sustainable neighborhood. As the building is a complex system (Kurtz and Snowden, 2003) in which the relationships between numerous variables are not linear, the analysis of the system is proposed through quasi-experimentation (Campbell and Stanley, 2015). The intervention is based on a Community Based Social Marketing (CBSM) (McKenzie-Mohr, 2000) and LL method and evaluate the effects on the dependent variable: **EPG**. The LL method can be considered as "extreme citizen science" as the stakeholders are engaged at every stage of the research project (Dickinson et al., 2012): in co-designing the research and the artefact, participating in the collection of the research data. The role of the researcher changes to become a facilitator (Sanders and Stappers, 2008) in a LL ecosystem.

6.2.2 The social offering

What is the "social performance" of low consumption buildings? Is there a "social performance gap"? How to measure it? The concept of "value-in-use" (Vargo and Lusch, 2004) helps to understand the "technology-in-use" (Geels, 2004). The value of the service is always co-created when the service is consumed by the "occupants". The energy lost while heating a room when it is not occupied does not create any value for the inhabitants. It is conceptually interesting but operationally complicated to measure (Skaržauskaitė, 2013). We propose to use the concept of satisfaction, abundantly described in the literature, which is defined as **the discrepancy between the expectations and the perceived service quality** (Parasuraman et al., 1988). A first satisfaction survey in the neighborhood reveals that when the quality of the energy service is not optimal (ex.: a dysfunctional heating system), the satisfaction to live in the neighborhood is lower. The contrary is not true: there is an asymmetry in the perception of the quality of energy services. High quality energy services are intangible, not always perceived and seem to be taken for granted. The social offering is the decrease of the overall EPG, with a constant or increased "social performance" measured with the concepts of value-in-use and satisfaction.

6.2.3 Engagement and exchange

The stakeholders' engagement is the core of the LL method. In our Living Lab, a standard process is used (Mastelic et al, 2017[21]). Referring to Hastings' paper, we are "rebels with a cause" and it is a matter of respect and trust to co-develop solutions with stakeholders: *"If we listen to and respect the people we work with to the extent that we claim, we should have the confidence to trust them with finding their own solutions."* (Hastings, 2017, p.9). This will be detailed in the section dedicated to co-design.

6.2.4 Competition analysis and action

In a LL setting, it is important to involve all the stakeholders in the co-design of the EE plan. The utility providing the district heating system in the neighborhood is publicly owned. Different providers are proposing services to optimize the energy consumption. The LL acts as a platform to support collaboration among the actors, which are sometimes in co-opetition (Zineldin, 2004). The idea is to find a win-win solution in the eco-system.

6.2.5 Segmentation and insight

As marketers, we "traditionally" segment consumers top-down, based on socio-demographic and attitude data. In LL, the approach is bottom-up and the consumers are seen as key partners. As we combine both approaches, we have tested different types of segmentation: (1) "Traditional" socio-demographic segmentation of the inhabitants compared to clustering of similar energy consumption curves. The level of explanation of the socio-demographic data on consumption curves was weak (Cimmino, Genoud and Mastelic, 2016). (2) We also separated owners and renters with the hypothesis it induced different energy performances. (3) We separated flats with and without smart meter to measure the impact of smart meters on energy performance (information flow in the system). (4) We then changed the unit of analysis and segmented practices influencing energy consumption and studied their impact on performance.

[21] Chapter 5 of this thesis.

6.2.6 Integrated intervention mix

Heiskanen suggests combining different types of users' interactions (2009). We propose a sequential multi-method research with a team from marketing, engineering and econometrics. We begin by analyzing the energy consumption in the neighborhood and compare it with the norms. First hypotheses are drawn on the determinants of the technical performance gap. Close attention is dedicated to default setting regarding artefacts, actors and rules. We then select a practice and study the involved stakeholders with a power/interest matrix (Bryson, 2004). Practices are studied in qualitative face-to-face interviews with all the stakeholders and ethnographic immersions; barriers toward energy performance are extracted. Then an inquiry in the neighborhood measures the "social performance gap" of the energy services. Personas are created from the data collected in the interviews (Miaskiewicz and Kozar, 2011). They become the basis of a serious game played with the stakeholders during co-design workshops where ideas of EE interventions are co-designed. They will then be integrated in a plan combining EE and marketing. After the quasi-experiment in the neighborhood, the impact of the EE plan will be measured with econometric analysis (stochastic frontier analysis) based on a combination of smart meter data, utility invoicing data, quantitative enquiry of inhabitants. Recommendations are proposed to the constructor, the labelling institution, the national office for energy, the smart meter producer.

6.2.7 Co-creation through social markets

The word "co-creation" can be understood differently depending on the phases of the service lifecycle: (1) **in the operation phase**: Vargo and Lusch see the consumer as a co-creator of value-in-use when the service is consumed (simultaneity) (2004). (2) **In the design phase**: the stakeholders are integrated in the innovation process to co-design the service (open innovation and LL processes). It is an outside-in process, as mentioned by Chesbrough (2006). In this case, we propose to co-design the intervention with the stakeholders. It is a mean of "extracting" community-based (Lee and Cole, 2003) tacit knowledge (Lin, 2007) and to be able to mobilize the knowledge to understand the barriers and co-design an intervention.

6.2.8 Systematic planning

We propose to combine CBSM and the LL processes to integrate the stakeholders in the co-design of an EE plan in a social practice theory perspective. To measure the EPG, we propose a new conceptual model considering the links and potential tradeoffs between (1) social, (2) technical and (3) economic performance measured by econometric models. This process combines social marketing, econometrics and engineering, as presented in the Figure 24:

Figure 24. CBSM process in a Living Lab, Adapted from McKenzie-Mohr (2000).

6.3 Results

The result of a theory building paper is the conceptual model itself. We will define below the concepts and how they are related. In our perspective, the EPG is composed of: (1) technical performance gap, (2) economic performance gap, (3) social performance gap, as showed in Figure 25:

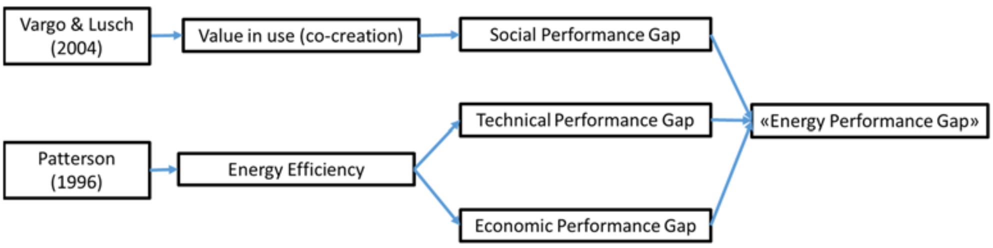

Figure 25. Multi-dimensional model of energy performance gap.

The technical and economic performance gaps are dimensions abundantly defined in the literature (Burman et al., 2014; de Wilde, 2014; Jaffe and Stavins, 1994). Burman et al. propose different methods to decrease the gap: (1) Improving the calculation/simulation methodology, (2) Feedback loop between operation and design (2012). The LL method permits to integrate a feedback loop to stakeholders and to give advice on the architectural norms. It allows a feedforward loop as well to design future sustainable neighborhoods. These descriptions of the EPG and the proposed interventions do not take into account the "**social performance gap**" of the energy services. Coleman and Robinson propose to measure a "qualitative performance gap" (2017). Our theoretical model combines the three dimensions, with the advantage of proposing quantitative indicators from marketing such as for instance the importance/performance matrix (Martilla and James, 1977) and the SERVQUAL method (Parasuraman et al., 1988).

6.4 Discussion/Conclusion

6.4.1 Evaluation

Heiskanen proposed already the use of LL methods as a systematic approach for piloting experiments. However, few quantitative evaluation papers exist. To further develop empirical results, we will run a new survey and a quasi-experiment in the neighborhood. The preliminary results after the qualitative interviews and co-design workshops indicate numerous barriers toward energy performance as energy services are intangible, heterogeneous, produced and consumed simultaneously and embedded in other consumed services. Econometric models will be used to measure the impact of the quasi-experiment in the sustainable neighborhood.

6.4.2 Discussion

Measuring "social performance gap" is essential to understand EPG. The interactions between technical artefacts, actors and rules are not optimal in the studied neighborhood. An example is the temperature: the architectural norm imposes 21 degrees, which is not perceived as a comfortable temperature for elder people in social apartments. The artefact to regulate the temperature indicate 25 degrees but the neighborhood is calibrated for 21 degrees. Numerous real estate agencies rent the apartments and there is no "official story" (Coleman and Robinson, 2017) which generates different expectations from the inhabitants. Some of them did not even know a maximal temperature was set. The district heating system has not been regulated after the construction and there is no contracting to optimize the operation. When co-designing an intervention in this complex system, we will focus on the role of the context (Coorevits &

Jacobs, 2017; Heiskanen et al., 2009) and the default setting in term of actors, rules and artefacts (Geels, 2004). Dessart and Bavel propose to combine behavioral economics and social marketing (2017). Sunstein would recommend acting on “default rules” instead of “active choice” in this case (2017). We are proposing **to co-design the default setting of the ST-System with the stakeholders**. It permits to counteract paternalistic decision from one single change agent (often architects or engineers), and increase the penetration of the plan.

6.4.3 Conclusion

Both our new conceptual model and research method are at the intersection of social marketing, economics and engineering. We propose to analyze the EPG with three dimensions: (1) Technical performance gap, (2) Economic performance gap, (3) Social performance gap. It will help understanding the interactions between rules, artefacts and actors. The co-design of interventions with the stakeholders could increase the social adoption of the EE plan. The originality of this exploratory research lies in the combination of CBSM and LL approaches to run a trans-disciplinary intervention measured with econometric models.

6.5 Notes on chapter 6

This article has been presented at the conference of the European Social Marketing Association. This scientific conference has provided a strict template for papers submissions which was formatted. Even the sub-titles of the short papers have been imposed. To complete all the parts, the author had to answer specific questions of the template, which was was oriented toward the description of a process in a case study of a social marketing intervention. Presenting a theory building paper with this template was complicated. The imposed length of the paper was also a strong constraint. In the following note, some complements are proposed to better understand how the author defines the notion of "Social Performance Gap" of low consumption buildings and its potential operationalisation.

When trying to define the "Social Performance Gap", one must first define what "Performance" means. The webster online dictionary proposes multiple definitions[22]: 1. a) The execution of an action. b) Something accomplished. 2. The fulfilment of a claim, promise, or request. 3. a) The action of representing a character in a play, b) a public presentation or exhibition a benefit performance. 4. a) The ability to perform : **efficiency**, b) The manner in which a mechanism performs. 5. The manner of reacting to stimuli. In our case, we define "performance" as in definition 2: "Fulfilment of a claim, promise, or request" and definition 4. "The ability to perform: efficiency", "The manner in which a mechanism performs".

Chapter 1 has contributed to define a concept close to "Energy Performance", the concept of "Energy Efficiency": *"Energy efficiency is a generic term, and there is* ***no one unequivocal quantitative measure*** *of 'energy efficiency.' Instead, one must rely on* ***a series of indicators*** *to quantify changes in energy efficiency. In general, energy efficiency refers to using less energy* ***to produce the same amount of services*** *or useful output." (*Patterson, 1996, p. 1 as Figure 26):

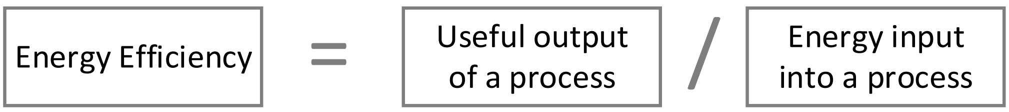

Figure 26. What is energy efficiency?, Adapted from Patterson et al, (1996).

[22] Source: https://www.merriam-webster.com/dictionary/performance

We will rely on **different types of indicators** as well to define the term “Energy Performance”. Three types of indicators are proposed measuring: (1) Technical Performance, (2) Economic Performance and (3) Social Performance. We are concentrated in this thesis on the “Social Performance” indicators as a gap is identified in the literature.

If we use the definition of the term "**social**" quoted in Chapter 1 from the same dictionary[23]: *"Social: of or relating to human society, the interaction of the individual and the group, or the welfare of human beings as members of society"*. The “**social performance**” is seen as the “*fulfilment of a claim, promise, or request*” for “*the welfare of human beings as members of society”*.
Referring to Patterson (1996), the useful output of the process is the delivery of the service. Fell has contributed in defining the “Energy Service”: *“Energy services are those functions performed using energy which are means to obtain or facilitate desired end services or states.”* Fell differenciates the energy service and the end service (2017), as illustrated in Figure 27.

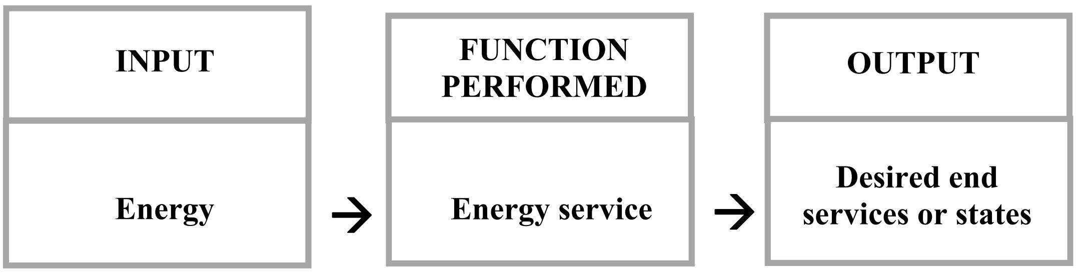

Figure 27. What is an energy service?, adapted from Fell (2017).

The current definition and operationalisation of “energy efficiency” and “energy services” come from the engineering and economics disciplines and are focused mainly on the measurement of the energy input into a process. The social marketing and service science contributions could be to measure, with different specific indicators, the “useful output of the process”: the performance of the process to reach the “**desired the end service or states**”.

Indeed, we are looking for a certain level of "end service or state" for the occupants of the low consumption buildings as part of the society. We are trying to maximize the useful outputs, the “desired end services or states” by limiting the input, the “primary energy” consumed. The Minergie label and the designation "sustainable neighborhood" hold out “promises” to

[23] https://www.merriam-webster.com/dictionary/social

stakeholders that must be fulfilled. The “end services” offered must be in line with the performance required by the inhabitants. However, certain end services are perceived as more important than others by the occupants.

Let us return to the notion of "**gap**" from the same dictionary: "*a problem caused by some disparity*"[24]. Combining the different definitions from the dictionary, “**Social Performance Gap**" is defined by the author as: “A problem caused by some disparity” (GAP) between the expected and the actual “fulfilment of the promise” (PERFORMANCE) for “the welfare of human beings as members of society” (SOCIAL). In the marketing discipline, the focus is on consumers of end services and the maximisation of the performance for these consumers. Another discipline could propose a wider definition of the term social “welfare of human beings” in a more macro level. Here, we will focus on a micro level, the welfare of the inhabitants as members of a sustainable neighbourhood.

In this article rooted in social marketing, we propose to use the concept of satisfaction, abundantly described in the literature to measure the “social performance gap” of the energy services. It is defined as **the discrepancy (gap) between the expectations and the perceived (end) service quality** (Parasuraman et al., 1988). There are plenty of quality indicators, the SERVQUAL method proposes for instance a standard process with 44 questions to assess the quality of each service by a service provider (Parasuraman et al., 1988). As we wanted to measure 12 different energy services, the SERVQUAL method could not be used. The length of the questionnaire with 12 energy services x 44 questions was not operationally realistic.

The chosen method is described in Martilla (1977). The method used was the **importance/performance matrix**. It proposes to map the level of satisfaction for each service on an axis and the level of importance of the energy service on the other axis. It indicates the performance of each energy service and gives priorities to act.

As an illustration of the method, we have run a survey in the sustainable neighborhood to understand the level of satisfaction regarding the different energy services such as heating, lighting, cooking… and the importance of each service. During the summer 2018, 100 households (out of 400) answered an online questionnaire.

[24] https://www.merriam-webster.com/dictionary/gap

We have performed this analysis, measuring the satisfaction and the importance of each energy service on a Likert scale with five points. The distance to the mean was used to map the satisfaction on the vertical axis and the importance of each energy service on the horizontal axis. The resultats of this analysis in the sustainable neighbourhood is illustrated in Figure 28.

The results confirm the technical issues we have discovered with the ventilating system as the mechanical ventilation is the worst result in term of satisfaction. It is also rated low in importance. The contrary is true for the manual opening of the windows. Users are satisfied with the possibility of opening the windows and they judge it very important. Mechanical ventilation is one of the important technical elements of Minergie label, often criticised by the users. In the matrix, Minergie is rated close to the mean in importance and in satisfaction. We will not elaborate on each service in this complementary note, but it is also interesting to mention the low satisfaction level on temperatures in the neighbourhood.

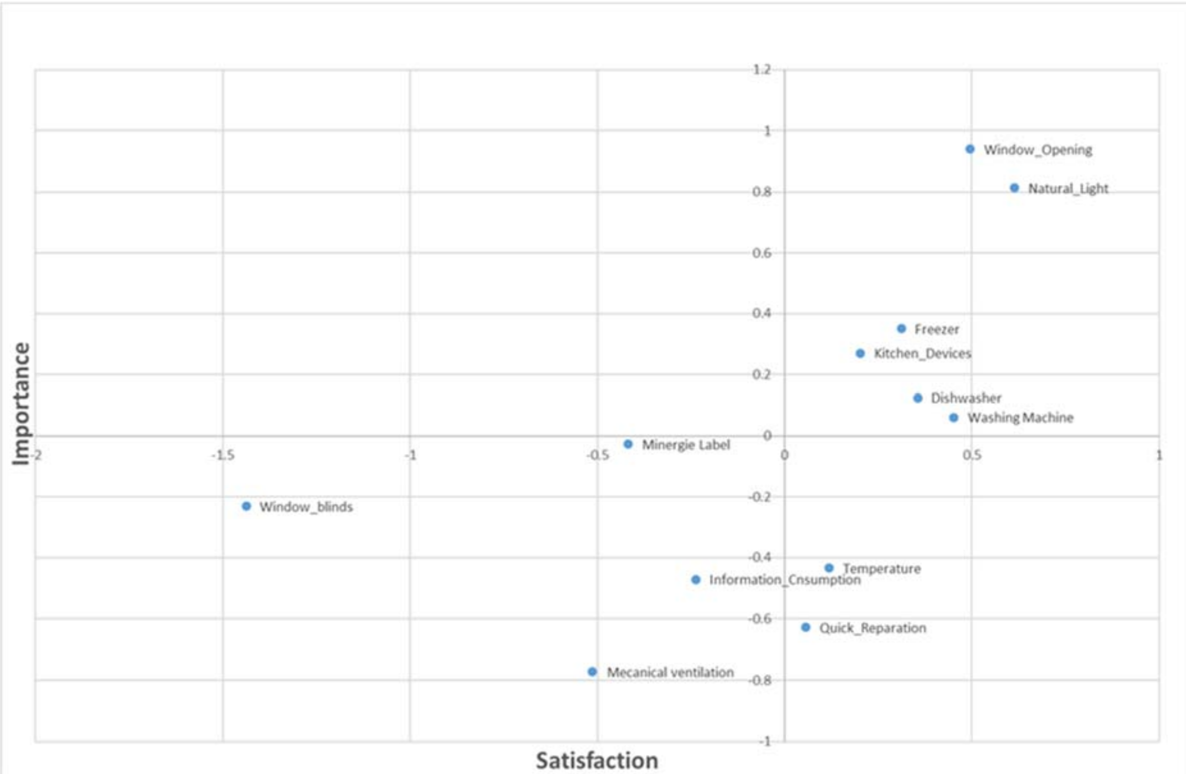

Figure 28. Importance/Performance Analysis, adapted from Martilla, (1977)

With the data of approximately 100 qualitative interviews conducted in the neighbourhood for three years, we can interpret this matrix. Engineers specialised in the building sector have also analysed the technical performance in the neighbourhood. There is probably a core quality problem on the ventilation system. The company operating the system got bankrupt and no maintenance was made on the system. Collected data on ventilation indicated a level far below what is acceptable (technical performance gap). The inhabitants are satisfied to be able to open the window, as in other studied low consumption buildings, windows are fixed and cannot be opened by the occupants. They use their "right" to open the window abundantly in the neighbourhood, the "social performance" of mechanical ventilation is really bad.

We can see on the matrix with the point "Window Opening", it is an important element of the building. From the semi-directed interviews, we have learned that some occupants complain about the mechanical ventilation system. The air debit is judged too low for some of them. In counterpart, they open the windows to ventilate. In the apartments, there are only two thermostats, one for the living room and one for the bedrooms. Parents often repeated in the interviews that they would like to regulate the temperature of each room separately. For the children, they appreciate a higher temperature than for the parents' room. The practice at the moment is to regulate the temperature of the children's' bedroom with the thermostat and to open their windows to get a lower temperature. The impact of the misfunctioning ventilation system on heating is probably strong, with the windows opened during long periods.

This example demonstrates how "social performance gap" could be measured operationally, using the importance/performance matrix from Martilla (1977). It is less precise than the SERVQUAL model but gives synthetic information on the "social performance" of the energy services in the neighborhood for the wellbeing of the inhabitants. This example illustrates also perfectly the fact that "behavior change" interventions alone cannot solve the issue of EPG. Interventions should focus on the social practices (opening the window), on the technical artefacts (adding a thermostat in each bedroom) and on the rules (changing the default set temperature). This is related to the three types of gaps in the Figure 29.

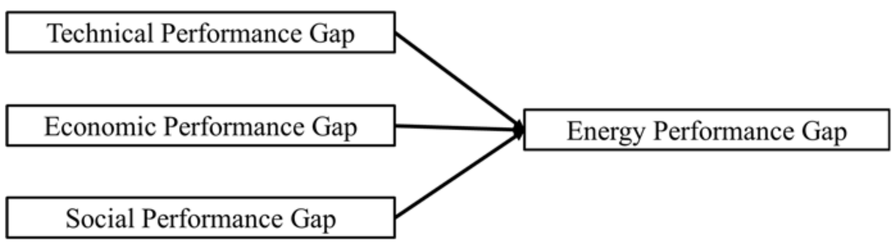

Figure 29. Conceptual Model of Energy Performance Gap.

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Chapter 7

District heating: How to avoid the main pitfalls?[26]

The vulgarisation of research is a competence to be developed by doctoral students. During the course of the present thesis, different articles have been published to disseminate the results of the studies in professional journals. The following article was published in French in *Bulletin*, the journal of the Swiss Association of Electricians in May 2017 and translated into English in this PhD thesis. It illustrates, with an example, how a Living Lab approach can be implemented concretely for the development of a District Heating System (DHS) and the benefits of this approach.

[26] Draft version before publication

District heating: How to avoid the main pitfalls?

Previdoli, D., Mastelic, J., Genoud, S., Papilloud, L, (2015), Chauffage à Distance. Comment éviter les principaux écueils, *Bulletin,* Association des Electriciens Suisses, May 2015.

When installing district heating systems, project promoters frequently encounter difficulties, both technical and from a human perspective. An analysis of potential barriers to adoption allows consumers to be involved from the beginning of the project and, thereby, increases the chances of success.

District heating systems (DHSs) are becoming increasingly popular in Switzerland. According to statistics from the Swiss Federal Office of Energy (SFOE), the final consumption of district heating amounted to 18,290 TJ in 2015 compared to 15,240 TJ in 2005, an increase of 20% over 10 years. Household waste is the most commonly used type of fuel (SFOE, 2016a). These DHSs flourish in both cities and villages and are considered 50% renewable energy. The Energy Management Lab has actively participated in the planning phases of several DHSs in French-speaking Switzerland. We aim to share these experiences with two very different examples in order to highlight potential pitfalls in various implementation contexts. The first, initiated by a municipality, will be built in Saint-Martin, a village in the Swiss Alps. The second, led by the company Sogaval, will be built in the city of Sion in Valais.

7.1 Context

When setting up a DHS, project promoters frequently encounter difficulties, both technical and from a human perspective. Indeed, this type of installation requires significant initial investments and a critical size to ensure its operation and profitability. The project developer must, therefore, convince nearby heat consumers to connect to the new system, either on an optional or mandatory basis. Depending on the location of the DHS, the issues also differ. For example, the heat consumption density threshold will be more difficult to achieve in a village facility than in a city. In its applied research and consulting activities, the Energy Management Lab offers companies and public authorities its expertise in the deployment of renewable energy solutions. A key step before deployment is a thorough analysis of potential barriers to adoption through qualitative and quantitative research. Such an analysis allows heat consumers to be involved early in the planning process, to co-design the energy solution with the consumers, and thus to anticipate potential pitfalls. The quadruple Helix is illustrated in Figure 30.

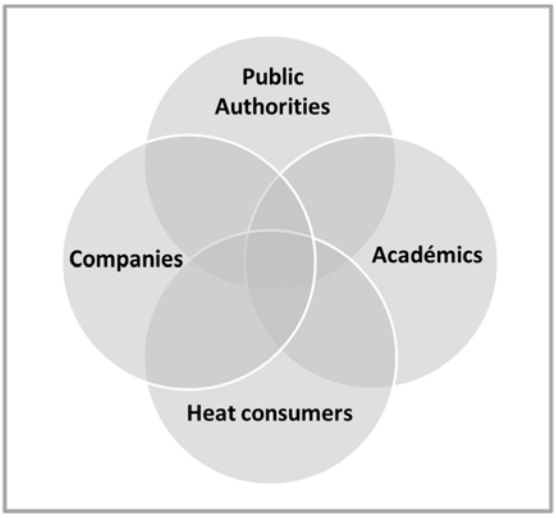

Figure 30. Ecosystem of stakeholders in the DHS

7.2 Methodology

As the role of the local context is very important, the analysis of the macro-environment with the PESTEL model has been conducted and makes it possible to structure the potential barriers as six categories: political, economic, sociological, technological, environmental, and legal. As prospect perception is central when there is no obligation to connect, we collected qualitative data during face-to-face interviews with potential heat consumers (residents, private and public companies). We also studied barriers to adoption through observations at public information sessions. Prospect perceptions are reported in the form of anonymous verbatim remarks in this article. A quantitative study using questionnaires with residents was also conducted as part of the Sion DHS study.

7.3 Barriers to the adoption of a DHS

Why study contextual barriers to technology adoption? In the field of sustainable development and energy, the motivational levers for adoption are often more obvious and express themselves more spontaneously, for example, through a qualitative interview. By contrast, barriers to adoption may be tacit, subject to perceptual biases such as the image one wishes to project, and may be expressed only as weak signals that need to be interpreted. An interesting model based on social marketing and called "community-based social marketing" was proposed by McKenzie-Mohr (2000). It integrates barriers as a central element to be overcome through targeted strategies and field pilot studies. In the following section, the results of the studies conducted will be structured using the previously proposed PESTEL model. This is a first phase that should precede the co-development of field pilot studies with prospective heat consumers' and other stakeholders such as public authorities and local businesses.

7.3.1 Political

National, regional, and municipal public authorities play a central role: at the national level, to set energy policies for the energy transition; at the state level, subsidies can promote the development of projects; and finally, at the municipal level as project leader, independently or within a public–private partnership (e.g., industrial services, waste incineration plants, etc.). In Valais, for example, the canton subsidizes the installation of a DHS if it replaces a heating system that uses fossil fuels and at least 75% of the heat comes from renewable energies or thermal waste; other states offer similar subsidies. Some municipalities have established an energy policy as well as territorial planning to assists its implementation. Although the vast majority of DHSs are initiated by municipal authorities or industrial services, the municipality has the choice whether or not to support the project's implementation. In the municipality of Saint-Martin in Valais, the installation will connect public and private buildings in the heart of the village, and the project is being carried out by the municipal authority with the support of the Energy Management Lab. Louis Moix, former president of the municipality of Saint-Martin and initiator of the project, explains: "The municipalities are in the best position to initiate DHS projects for two reasons: The municipality is aware of the regional specificities related to the energy used (type of heating, etc.), and moreover, it can more easily mobilize citizens around a project than an individual." He also points out that this adds credibility to the project.

7.3.2 Economic

The construction and operation of district heating systems involve significant costs. First, the cost of different fuels influences the economic profitability of a project. The price of oil, which currently is extremely low, fell by 75% from June 2014 to mid-February 2016 (SFOEb, 2016). Natural gas prices are also relatively low and expected to remain so according to the

International Energy Agency (IEA, 2016). Wood pellets, on the other hand, are currently priced similar to fuel oil. In November 2016, one kilowatt-hour of pellets costs CHF 0.749 cents compared to CHF 0.741 for fuel oil (Prix Pellets, 2016). This similarity is probably due to the adjustment of wood pellet prices to the price of their fossil-fuel competitor. According to a benchmark of the prices of the various DHSs conducted by the Energy Management Lab in 2015, the price per kilowatt-hour for heat is indexed mainly to the price of oil regardless of the fuel used. One of the undeniable advantages of DHSs' use of renewable energies is precisely a potential dissociation between the price of heat and the price of fossil fuels. This element must be presented to future customers and considered a strong argument in the event of a possible increase in the price of fossil-fuel energy. An economy of scale is also necessary because the costs incurred by the excavations related to the installation of the connections are relatively high. It is, therefore, necessary to have as many connections as possible along the pipe route and to avoid connecting a few scattered buildings within an urban area. The pipe path must then be optimized to minimize the length of the pipes while maximizing the number of connections. The cost of preliminary studies and the variants should also be taken into account as they represent approximately 10% of the total cost, which is a significant amount. In addition, it is sometimes advisable to limit preliminary studies to a reasonable number of variants in order to maintain a clear vision of the project.

The total cost of a DHS will depend mainly on the distance to be covered, the number of connections, and the power requested. Forecasts are thus necessary, especially since the cost of making the transition is a decisive factor when asking the potential consumers directly about their interest in the installation. Unfortunately, it is challenging to provide a precise answer to this question until the exact number of connections is known. We believe it is essential to present citizens with a detailed estimate of the installation price and to gain their trust by making the most accurate information available. During the many interviews conducted, it became clear that a number of respondents wanted to obtain a new heater at the same price as their current installation. A building administrator told us: "*Connecting to the DHS should not cost more than changing the gas boiler*." However, an exact figure is not very useful because the majority of people do not know the cost of their present heating system. Therefore, it is preferable to give them a comparison of the overall cost of district heating with the overall cost of their current installation. Building management has raised an important issue in relation to rental buildings. As they represent the interests of the owners, they strive to have the lowest possible charges in order to increase the owner's profit. One manager explained it this way: "A tenant pays CHF 1,600/month, for example. Whether it is CHF 1,200 in rent and CHF 400 in charges or CHF 1,500 in rent and CHF 100 in charges, the tenant always pays CHF 1,600. So the more you reduce the charges, the more you can increase the rent, the property owner's share." This factor also plays a role in the competitiveness of buildings. However, the inclusion of heating costs for residential leases is governed by the Ordinance on Rental Leases and Farm Leases of Housing and Commercial Premises. It is, therefore, necessary to ensure that heating costs comply with this ordinance; otherwise, there is a risk of contesting the costs charged to tenants.

7.3.3 Social

In the context of heating in general, the question of comfort is central because it is one of the basic physiological needs illustrated in Maslow's hierarchy of needs pyramid (1943). The concept of comfort varies significantly depending on the cultural context. In Switzerland, the Swiss Society of Engineers and Architects SIA recommends a maximum temperature of 21°C in dwellings, whereas this temperature may seem high to our French neighbors. This is an important point if we take into account that each additional degree represents an increase in consumption of about 7%. This notion of comfort also varies according to the target audience, especially in regard to older persons and young children. This is the case of district heating in Saint-Martin, which will have to supply the “Maison des Générations,” a group of living spaces for these two target groups with specific needs. Questions that have arisen include the following: “How can the DHS manager ensure that his facility will have the necessary resources to supply all connected buildings?” “Will the building at the end of the network have enough heat available?” “Will the facility operate annually and 24 hours a day?”

In summary, the issue of ensuring occupants’ comfort is of paramount importance to building operators. Reliability is, therefore, one of the main criteria. One hotelier in the region stated: “*If you have to pay a little more for reliability, you do it*.” Outsourcing heating also allows them to focus on their core business and not have to worry about how the heating works. “*We also want peace of mind, it has to work well*,” added a company manager. Contracting is, therefore, an option to be considered and one that makes it possible to bypass the barrier of lack of cash. One of the levers of action for DHSs is related to the use of local energy. Indeed, local supply undeniably strengthens the regional economy. In the case of Saint-Martin, a wood supplier would use the salary earned to purchase other goods, certainly in the region. DHSs are, thus, good examples of circular economies, and the visual illustration of origin can play a key role in understanding the actors in the territory, just like oil companies that have to travel long distances to supply us with fossil-fuel energy.

7.3.4 Ecological

In both situations studied, seldom-exploited and regional energy sources (household waste and wood from a nearby forest) are involved. This greatly motivates citizens to connect to the new facility. Regarding the DHS supplied by household waste, one building administrator said that it allowed "*the energy that goes up in smoke to be used*." Explained another person, "*You have to find the right balance between price and the environment*." A potential additional cost for the use of renewable energy may be acceptable "*if it corresponds to a maximum of 10% of the cost of non-renewable fuel*," a building administrator told us. The majority of respondents are willing to pay a small extra cost, offset by the regional origin of the energy. In the case of Sion, a minority of people think that household waste costs nothing and, therefore, the cost of energy should be lower. Some even perceive the waste tax as a kind of "*barrier to the adoption of a DHS*" and refuse to pay more for energy produced by the combustion of households' waste because they consider that they have paid for it already through the waste tax. Although this perception is not directly related to heat production, it has been mentioned several times by heat consumers. In addition, the environmental impact of a remote installation is less significant than that of an individual installation; adjustments are generally better made; and emissions are reduced. Environmental services are particularly concerned with the dissemination of DHSs because they contribute to reducing CO^2 emissions.

7.3.5 Technological

From a technological perspective, it is important to choose the fuel best suited to the situation and corresponding to the needs of the users. In addition, a back-up system must be planned from the outset to avoid supply disruptions and ensure consistent comfort. In addition, in our experience, a minimum density of 3,000 kWh per linear meter is essential to the profitability of the installation. The layout is also a very important factor; it must follow economic and non-technical constraints and seek to connect large consumers as quickly as possible. The proponent must also be able to say "no" to a connection that is too far away and would affect the overall efficiency of the heating system. In Saint-Martin, for example, a number of buildings will not be connected because they are too far away from the heating system. It is the proponent's responsibility to be imaginative about construction solutions by using all opportunities to reduce implementation costs. Sharing costs with other excavation work, such as the installation of optical fiber, is a good way of thinking about this. The timing of the project is also essential. Indeed, the proponent must be able to submit a bid at the optimal time by anticipating possible boiler changes in the main buildings in the vicinity. The degree of urgency to change the boiler and the propensity of consumers to connect can be represented in a matrix format to define an order of priority. If several representatives of buildings who are interviewed will soon have to change their boilers for various reasons, it is important to approach them and, if necessary, offer an alternative while waiting for the final connection to the DHS.

7.3.6 Legal

Many legal rules are in force for the construction of a DHS. The installation must comply with the Air Protection Ordinance (OPair) governing fuel standards and the permissible pollutant load in the air. This ordinance defines the height of the chimney because, according to article 6, paragraph 2, "*their discharges will generally be made above the roofs, through a chimney or a discharge duct*." This is a factor to take into account when choosing the location. Depending on the parameters, the chimney height can be relatively high. In Saint-Martin (a small village comprised mainly of chalets), a variant proposed a chimney 8 meters higher than the height of the highest roof in the vicinity of the installation, a variant that was quickly abandoned [because it was unaesthetic]. The ordinance also defines the emission-limit values to be respected according to the type of fuel. In 2014, the Swiss Association of Waste Facility Operators signed an agreement with the Federal Department of the Environment, Transport, Energy and Communications to reduce their CO^2 emissions by 2020. The production of heat and electricity by these plants indirectly contributes to the reduction of emissions. This agreement, therefore, constitutes a legal incentive for the implementation of DHSs. The graph of the Swiss Association of Waste Facility Operators (ASED) (Figure 31) shows the percentage of heat and electricity produced per facility in 2015, as well as the amount of waste recovered (circle size). All the plants located below on the right are of interest because they have a high potential for improvement. Other legal obligations that promote the implementation of DHSs are neighborhood plans and municipal regulations. A municipality in Valais requires new buildings within the DHS perimeter to be connected to it.

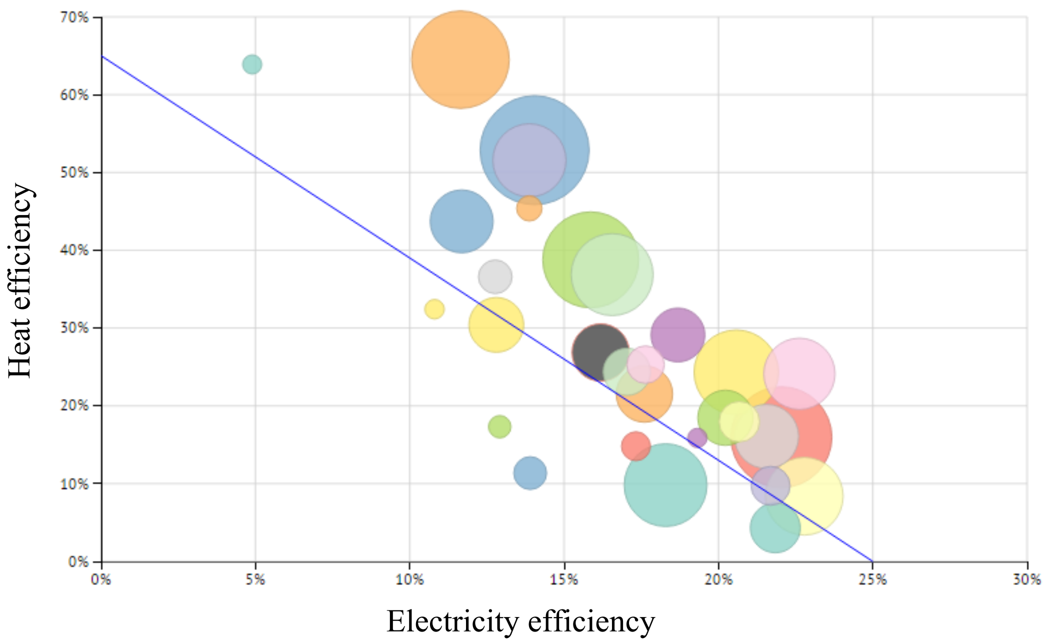

Figure 31: Percentage of heat and electricity produced per installation in 2015, adapted from ASED

7.4 How does the Living Lab avoid pitfalls?

The Energy Management Lab proposes to study the barriers to the adoption of DHSs in situ, i.e., at the site of heat consumption, in the company or in the home. Then, in a Living Lab or living laboratory approach, all stakeholders participate in the development of the pilot solution, which aims to overcome barriers to adoption: public authorities (municipalities of Saint-Martin and Sion), energy-distribution companies, engineering firms, energy suppliers, etc., and academics (HES-SO Valais-Wallis, EPFL Valais) and heat consumers. Agile methods allow regular communication between the field and the project. From our experience, heat consumers expect clear and transparent answers to their questions. In order to remove barriers, we recommend organizing an information evening with plenty of time available for dialogue so that stakeholders can ask questions to an external expert and, thus, problems can be known in advance. In addition, the technical questions that emerged during the qualitative interviews are forwarded to the technical manager of the installation, who responds quickly thereafter. The visualization of the benefits of the DHS, unlike fossil fuels, also seems important. This approach made it possible to co-design the projects with the stakeholders but also the financial offers. By reaching out to stakeholders, particularly heat consumers, they feel valued and involved. They realize that the project leader has to answer many questions in order to offer a service that meets the needs of his future customers. Louis Moix, former president of the municipality of Saint-Martin, compares this approach to *Ringi,* a Japanese system that integrates the entire hierarchy of a company (in decision-making). According to the latter, the advantages of integrating citizens are obvious: arousing interest and curiosity for the project, answering latent questions from the outset, involving and motivating interested people, eliminating resistance along the way and, at the end of the process, quickly implementing the project that the actors are able to appropriate. By contrast, Moix believes that a project developed solely by public authorities or the hierarchy must then be "sold," and doing so requires a great deal of effort, information, and persuasion, and often leads to failure. He adds: "*Good information cuts short rumors, false information, and deliberately misleading information spread by opponents of a project.*" The people involved particularly appreciated that their interests and needs in terms of heating were taken into consideration. One person summarized this common opinion as follows: "*I find it very interesting to involve all the actors and end consumers in the upstream reflection*." In addition, the majority of the people interviewed in Saint-Martin and Sion were interested in a connection and thought that it could be a solution for their buildings. They also wanted to be regularly informed about the progress of the project.

7.5 Conclusion

Good planning for the DHS project is undoubtedly the key to anticipating the main pitfalls upstream, and carefully thought-out timing, in collaboration with urban services, will allow a harmonious deployment. In addition, the development of local and, if possible, renewable energy sources will enable the project to align itself with the energy policies that are also valued by the population. Legal constraints can be used as levers to trigger projects. On the other hand, it is necessary to use good intelligence and, if possible, to favor dialogue with all stakeholders and resort to obligation only if other means have not had the desired effect, at the risk of pushing heat consumers. The route will have to be considered in terms of physical barriers as well as economic barriers to favor a sufficient density of consumption per linear meter. As the Pareto 80/20 rule is also applicable here, particular care must be taken to meet the needs of large consumers by correctly anticipating the opportunities presented by boiler changes. Service models such as contracting can be powerful tools when cash flow is a major barrier. The circular economy model of this type of approach can be highlighted. It requires the trust of the stakeholders, hence the importance of renewing opportunities to interact with the ecosystem in question. Finally, many interviewees felt concerned about the project and spontaneously put forward ideas to help it run smoothly. Thereby, they have taken ownership of the project and no longer need to be pushed to accept it. The participation of all stakeholders, therefore, seems to play a key role in the smooth implementation of the project.

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Chapter 8

The value of participatory approaches in developing energy services

What is the contribution of participatory approaches, such as Living Labs, to the development of energy services? This doctoral thesis has attempted to answer the question, and the following chapter focuses on it. This is a vulgarisation article that was submitted in a shorter version to *Le Bulletin,* the journal of the Swiss Electricians Association. The objective is to simplify and disseminate the approach so that professionals in the field can use it independently and measure its results. This article summarizes the previous chapters in a condensed version that can be more quickly assimilated by a professional audience. Thus, the impact sought is mainly managerial.

The value of participatory approaches in developing energy services

Mastelic, J., Genoud, S., (2019), *le Bulletin*, Journal of the Swiss Electricians Association, April 2019.

8.1 The context: Energy services and stakeholders

This article, based on a recent doctoral thesis in environmental sciences, proposes approaches for integrating stakeholders in the development of energy services.

8.1.1 What is an energy service?

A 2017 study by Michael James Fell indicates that only 0.5% of the 185 scientific articles analyzed by two major energy journals mention "energy service," and only 10% of these studies define what an energy service is. Clarification has, therefore, been required, and Fell proposes the following definition: "*Energy services are those functions performed with energy that are means of obtaining or facilitating the desired services or end states*." Lighting, for example, is an energy service that can be produced using different primary energy sources and leads to a desired end state: illumination in the home or office. How does this service create value? According to marketing researchers Vargo and Lusch, value creation occurs when the service is consumed by the customer (2004). A watt lost during transport does not create any value. In marketing, we are considering the consumer as a co-creator of value. It is, therefore, always a value perceived by the consumer.

It is sometimes thought that consumers are not rational, for example, when they leave windows open in winter. From their point of view, their actions are rational because otherwise they would not behave in this way. For a specialist, it is often difficult to put oneself in the consumer's shoes and understand these types of practices that are detrimental to energy efficiency (EE) and the environment.

8.1.2 The intangibility of energy services

This perceived value causes problems for energy service providers. Indeed, the value of services is often not perceived. Users expect to benefit from services such as heating, lighting, and ventilation. They realize the value of such services only when they experience poor quality or an interruption in service. This is what we were able to measure in a previous project in a sustainable neighborhood (Mastelic et al., 2016). When the heating system fails in the middle of winter, the value of the energy service is realized by its absence. How, then, can we raise awareness among users of the value of energy services when everything is working well? It is a challenge to make energy tangible, to make it visible. Today, we are witnessing a decoupling between primary energy and "the desired end state". During our grandparents' time, people were well aware of the primary energy needed because they had to feed the fire to warm their homes. They had to cut wood, carry it, dry it, and manage the supply to the furnace or woodstove so as not to let the temperature drop. There was a direct and tangible link between primary energy and the desired end state. And what our grandparents experienced 100 years ago, our African neighbors still experience every day. In Europe today, it is mostly an automatic system that does the work for us, and as a result, most of us have lost this link with primary energy.

8.1.3 Raising user awareness

We then consider solutions to make the population aware of energy savings. Appealing to users' common sense, we think we can solve the problem by carrying out educational actions. Unfortunately, for the past two decades, science has indicated that, although necessary, awareness and education are not enough to get users to take the desired actions (McKenzie-Mohr, 2000). It is also difficult to produce lasting effects over time, and this type of intervention must be repeated. Admittedly, mentalities have changed, and today, a larger segment of the population declares that it wishes to act in favor of the environment. Attention must be paid to the potential gap between attitudes, intentions, and actions (Kollmuss and Agyeman, 2002). In a sustainable district that we studied and according to the results of the tree of correlations between the satisfaction of living in the district and the various services provided, energy was not among the priorities; they were looking first for satisfactory social relations, an attractive place to live, and a location (Mastelic et al., 2016).

8.1.4 Limited perceived control

We have also observed in our studies that the power to act personally is often underestimated by stakeholders. Most people think there are other, more competent people who will act to increase EE. The problem is not being addressed, as demonstrated by our study on the development of an energy management system (Mastelic et al., 2017). If no EE targets are set by management, employees will not take the ownership of the challenge and leave it to the management team. If employees (and especially custodians) are not measured annually on their energy performance, then why should they act? In addition, stakeholders often do not have much knowledge about energy; they have low "energy literacy." The notion of kW/h is highly abstract for them, and they don't know how much it can represent. Most of the people we interviewed in our studies over the past five years do not know how much they spend on energy, and even if they do, the percentage is a relatively low one based on their total budget (about the price of a cup of coffee a day for electricity in a household) and, thus, provides little incentive for EE actions. Subsidies can, to some extent, provide an incentive for action.

8.1.5 Automation of energy services

EE specialists, therefore, imagine increasingly complex technical systems that can solve problems. These include automatic lighting with presence sensors, regulation of temperature control in buildings according to theoretical occupancy data, and the use of windows that prevent opening. They use technical and economic models to implement them and sometimes forget that these systems will interact with users. Indeed, as proposed by Geels, they are socio-technical systems composed of rules, technical artifacts, and human actors (2004). User are sometimes forgotten or relegated to the end of the process to test the final service, thought of in a patriarchal way as: *"We know what is good for you"*. Users often do not oppose active resistance in this phase as they have a low technical knowledge and tend to delegate ownership of the challenge to experts.

The problem is that, if the technical solution and/or the rules put into place (system regulation, laws...) do not meet their requirements, users will find inventive ways to try to circumvent the system (bypass use). When specialists encounter blockages, we are often asked for interventions that promote "social acceptance," a kind of magic wand that would be used to accept technical solutions which do not work optimally. Unfortunately, it is often too late to change the technical artefacts, and only small adjustments can be proposed. It is, indeed, at the start that action should be taken.

8.2. Ways to promote stakeholder engagement

The research question of this thesis is how to engage stakeholders in a co-design process to co-develop energy services. The following section give recommandations for professionals.

8.2.1 Transformative research and quasi-experimentation

When we want to act on energy services, we act on a complex system. In such a system, the relationships between variables are not linear, and the preferred way to test whether or not an intervention has an effect is through experimentation (Kurtz and Snowden, 2003). This is referred to as quasi-experimentation because we do not have a random sample of the population. In addition, we work in the field, *in situ*, and therefore, we cannot control all the variables in the system. The effects of certain variables, such as the influence of weather on energy consumption, must therefore be considered.

We are attempting to move from one energy system to another, so we want to change the reality we observe. This is not considered acceptable in all scientific disciplines. We are in a constructivist epistemological paradigm: the researcher is not neutral; we conduct action research that is called "transformative" because it transforms the observed reality (Schneidewind, 2016). This is the approach that was tested in the doctoral thesis, several selected elements of which are presented below (Mastelic, 2019). The author tested the Living Lab approach to co-design energy services with stakeholders.

8.2.1 What is a Living Lab?

The Living Lab (LL) approach is relatively new. It has been in place for about ten years at the European level, but few experiments exist in the field of energy services. Research on the "Living Lab" phenomenon is, therefore, in its infancy. Definitions abound, but it remains difficult to capture the complexity of the phenomenon. Therefore, we proposed a new one as part of the thesis:

> *A Living Lab is an innovation intermediary, which orchestrates an ecosystem of actors in a specific region. Its goal is to co-design products and services, on an iterative way, with key stakeholders in a public private people partnership and in a real-life setting. One of the outcomes of this co-design process is the co-creation of social value (benefit). To achieve its objectives, the Living Lab mobilises existing innovation tools and methods or develop new ones.* (Mastelic, 2019)

What differentiates the Living Lab from other participatory methods is the combination of several factors, listed in the definition and detailed below:

1) An ecosystem of stakeholders: This laboratory emulates a partnership between public authorities, companies, citizens, and academics. The Living Lab manager acts as a catalyst to build a common vision, provide methods, coordinate experiments, and measure results.

2) Co-designing solutions: The prefix co- means "with." We do not develop solutions for users but rather with users.

3) An *in situ* environment: Research does not take place in a laboratory but in the place where energy is consumed or produced; it adapts to different contexts.

4) A societal-improvement objective: A strategy for individual well-being is not developed but rather societal well-being is the aim.

8.2.3 The Energy Living Lab

A Living Lab was created by the HES-SO in 2014 to support the development of field interventions and to help achieve the objectives of the Swiss Federal Council's Strategy 2050. It operates in two main sectors: increasing energy efficiency (particularly in the built environment) and the diffusion of renewable energies. After an initial test in the Chablais region, the Energy Living Lab increased its interventions in a portfolio of projects supported by public and private funds (work on the energy performance gap, the dissemination of renewable energies in a village, the dissemination of photovoltaics in French-speaking Switzerland, the deployment of district heating systems, etc.). Some of these interventions will illustrate the purpose and feedback below.

8.2.4 The process developed by the Energy Living Lab

The process is based on "Community-Based Social Marketing" as proposed by McKenzie-Mohr (2000) and integrates knowledge of social marketing and social psychology. Marketing gives particular importance to the choice of targets for interventions. You can't talk to "everyone" because it's the most effective way to avoid addressing anyone. Social marketing, then, focuses on barriers to pro-environmental or pro-social action. Understanding barriers is key to understanding why EE interventions fail. Measuring results is also central in marketing because, in order to achieve objectives, it is necessary to know how to determine performance indicators and how to measure them. As part of the research, we combined social marketing and the Living Lab approach; this involves analyzing and integrating key stakeholders from the beginning of the value chain. Non-specialist actors work alongside experts to co-design a solution (product/service/action plan). It is also important to go into the field quickly to test the proposed solution under development and then return to development iteratively (agile methods).

1) **Selecting a practice.** An analysis of existing data is conducted to determine which practice(s) we want to act on. In the sustainable district studied, for example, the focus was on heating and mobility. We attempt to take a step back and choose according to the context and data rather than choosing a field of use *a priori*. The PESTEL model (political, economic, social, technological, ecological, legal) can also be used to understand the complexity of the usage context.
2) **Integrating stakeholders.** Stakeholders are listed, and then a matrix is used to classify them, in this case, the power/interest matrix (Eden & Ackermann 1998, in Bryson, 2004). We look at who has the power and who has the interest in changing the service, for example, in the case of heating. If citizens are not the ones with the power to make an impact, why focus on them? We place our research hypotheses *a priori* in this matrix because we do not know *a priori* who has the power and interest. Efforts will also be made to integrate four types of stakeholders, the Quadruple Helix model (Carayannis & Campbell, 2012): academics, public authorities, companies, and citizens/users of the energy service.
3) **Identifying the Barriers.** Qualitative interviews will then be conducted with each of the key stakeholder groups based on the matrix, in order to better understand their perceptions regarding the level of power and interest, their motivations, and the barriers. In one of the fields studied, even the director of the school thought he did not have the power to change the situation (Mastelic et al., 2017). There was no energy-saving objective. Who does have the power if the director doesn't think he holds it? There is often a lack of ownership of the challenge. In LLs, the first step is to encourage stakeholders to take ownership of the challenge. This is achieved, for example, by asking the director in front of the stakeholder assembly: "What is your goal for energy

efficiency?" A public and voluntary commitment is necessary. This allows better ownership of the project and future results (Cialdini, 2001). Once we have completed this stakeholders' analysis, we compare our research hypotheses with what stakeholders have mentioned. We redraft a power/interest matrix in relation to their perspectives and see if there are any differences. We also analyze all the other barriers to action such as, for example, lack of cash flow, low motivation, and technical ignorance.

4) **Co-designing the solution.** We then collaborate with stakeholders to co-design a common vision. We have had cases where companies have seen municipalities as actors who are there only to place obstacles in their way. Conversely, sometimes municipalities see companies as interested only in their profit margins. If we do not offer this space for dialogue between actors to correct certain biases, they cannot co-develop a common vision. Qualitative interviews are always conducted first to gain a clear understanding of individual barriers to change and then to moderate this type of multi-stakeholder process that involves building trust between stakeholders (Dupont et al., 2018). Simply bringing people to the table and providing an environment that fosters trust and the development of a common vocabulary often helps to move the process forward. Many tools exist to co-design energy services and are presented in other works by the same authors.
5) **Piloting an experiment.** Primary importance is given to testing co-designed solutions in a real-world situation with authentic users. Agile methods facilitate regular trips back and forth between the experimental field and theory. Today, we see the emergence of laboratories in which researchers live and test new products and services. Although these experiences are similar to a real-world environment, they do not convey the actual and authentic conditions of use, including users' knowledge. Thus, barriers may be overlooked related to technology adoption, culture, lack of time, and a range of social factors that will not be reflected in the test environment.
6) **Evaluating performance.** A measurement and verification plan is proposed before the pilot. EE standards can be referred to, for example IPMVP[27]. A large volume of data is now available, such as energy consumption from smart meters. To interpret the results,

[27] International Performance Measurement and Verification Protocol

it is often useful to collect sociodemographic data using surveys and to cross-reference them with consumption data to provide analyses by consumers' clusters.

8.3. Impacts of Living Labs on energy services

The Living Lab approach, tested during the thesis in several research projects or mandates, is beneficial from many perspectives, as presented below.

8.3.1 Reducing barriers to change

The approach provides a better understanding of barriers to action from different perspectives. A new and "naive" look at the energy challenge is taken. Indeed, barriers are not always found where we expect to find them. An example is the development of district heating system (DHS) (Previdoli et al., 2015). The contracting authority thought that prospects could raise economic barriers, as the installation of the network has high initial costs. However, after stakeholder analyses, a different and unexpected barrier emerged: resistance to change from the environmental service. For years, the service had required the switch from oil to gas. With the arrival of the DHS, a new argument had to be developed to convince employees in contact with prospective users and then the prospects themselves. Without involving all key stakeholders and focusing only on users, this important barrier to deployment could have been missed.

8.3.2 Development of a common vision

An ecosystem of actors is integrated into the reflection from the very beginning of the projects. The first step is to network the partners and define a common vision. Interactions and mediation promote trust-building and knowledge-sharing (collective intelligence). The LL method makes it possible to build bridges between actors and between disciplines.

An example is the municipality of Saint-Martin. The president of the village called on the LL to develop renewable energies in the village. School children, aged 12 years old, teamed up with engineering and economics students from the HES-SO Valais to propose a renewable energy development plan for the municipality. The best project was selected by experts and presented by the young people to the primary assembly. The latter accepted the budget for the preliminary studies for the deployment of the plan in the village by local companies.

8.3.3 Increased perceived control by change agents

Stakeholders sometimes feel that they cannot act. The example of the hummingbird, cited by Pierre Rabhi, comes to mind. The little bird is the only animal who attempts to extinguish a raging forest fire by filling his beak with water and spraying it. The other animals tell him not to bother as he won't make a difference, and the tiny bird answers, "Maybe so, but I'm going to try." In our projects, stakeholders also need examples, support, and reassurance to give them confidence that they can act and have an impact. We tested the TupperWatt evenings, workshops that bring neighbors together around the theme of EE. An expert attends and presents technical solutions. The participants can freely express the obstacles they foresee, and the exchange of experiences is rich in learning. EE materials are then offered for sale, and participants are given a "good practice" guide and a small gift. In this way, they become aware that they can act at their own level. You can see an excerpt from this in the RTS program "One Planet."[28] (in French).

8.3.4 Changing the role of users

Users become active co-designers of the energy services and even sometimes prosumers. Users have often lost their link with primary energy; they have become passive consumers of automated services. As part of the LL's activities, we are trying to give them back an active role as co-designers alongside specialists. For example, as part of the UserGap project funded by the Swiss Federal Office for Energy, we have developed a serious game: the poker design (initially proposed by Cité du Design from St-Etienne). After conducting qualitative interviews with stakeholders, personas, a kind of stereotype of the system's actors, were created. For example, there is the energy distributor, the elderly person in subsidized housing, the employee of the real estate agency, etc. We then developed three types of cards: (1) persona, (2) actions, (3) uses. Stakeholders were able to combine the cards to develop an EE plan for their neighborhood. For example, the "energy distributor" card is chosen, which "encourages" the "inhabitants" to "install a HYDRAO shower head to save water." The persona allows users to take a step back from their own practices and to avoid guilt. The game stimulates discussions and the co-design of solutions to be implemented in the neighborhood.

[28] https://www.rts.ch/play/tv/emission/une-seule-planete?id=9664443

8.3.5 Increasing the social acceptance of systems

When stakeholders come up with ideas to improve energy services, they express their own needs. Co-designed solutions are closer to these needs. They are all the more easily adopted by the actors, even if they did not participate in the co-design process. In the example of Saint-Martin cited above, the whole village is behind the projects of mini hydraulic turbines in drinking water systems, joint tendering for solar panels on public and private roofs, and DHS in the village. The assembly unanimously voted the budgets to implement the plan developed by the children and students, and local companies are working on it.

8.3.6 Reconnection to primary energy

When working with participatory methods, actors re-examine questions that they had omitted, such as the source of primary energy ("Where does the energy I put in my car or in my heating system come from, and who benefits from the money I spend to purchase it?"). Several illustrations of this phenomenon can be cited. During the qualitative interviews conducted to understand the motivations and barriers of the actors to the deployment of a DHS, many understood the need to valorize the energy from waste rather than importing fuel oil (Previdoli et al., 2015). The mental images communicated are often more meaningful than the words: "Imagine the distance that fuel oil must travel in tankers and then by road to get here." The argument of local energy speaks to many and favors the circular economy: the forester who feeds the DHS with wood waste from the local forest reinvests his salary locally.

8.3.7 Piloting the co-designed service

The quasi-experiments used in the LL method allow the solutions to be tested *in situ* to see the results of the system. This allows quick round-trips between the field and R&D to adapt the energy service. For example, one idea that emerged several times in the co-design workshops was to develop a large red button for households to turn off all sources of unnecessary electricity consumption when leaving the house. This is a simple idea based on a common need and could be installed by default in senior citizens' housing, for example. Its implementation is more complex, however: Do we really want to cut everything off? This requires prior testing in a real-world setting, which is the case in the studied sustainable neighborhood.

8.4. Conclusions

How can we achieve the energy transition while engaging key stakeholders? The share of household energy consumption in Switzerland is very high, accounting for about 50% of the country's consumption. It is, therefore, illusory to imagine an energy transition without citizen. It is also completely unrealistic to imagine that, by giving them information only, this could be enough to get household users to drastically change their consumption practices. Although they represent about half of the country's energy consumption, these consumptions are highly diffuse throughout the country, with very varied uses. It is, therefore, difficult to establish a cost-effective economic process to help them reduce their consumption because, apart from communication solutions, which have demonstrated their limits, the time required to help them achieve an energy transition within the expected time frame generates significant consulting and support costs. This transition will have to be rapid and will be very difficult to achieve without effective participatory approaches. LL's approaches are perfectly aligned with this spirit, as co-designed solutions are more easily accepted. Many indicators demonstrate the awareness of the population—and young people, in particular—of the need to reduce our impacts on the environment. This is very encouraging and adds one more reason to help redefine market rules. We must accelerate the energy transition, for example, in the field of construction where, with a rate of 1% per year of renovation of existing buildings, it would take us 100 years to refurbish our real estate assets. We obviously don't have that time available. Today, a large part of the activities conducted by economic actors in Switzerland will have to be refocused on actions around the energy transition. This is also true for universities and the institutions that finance them. They should contribute with a managerial impact to the reduction of CO^2 emissions and the production of renewable energies, not only through theoretical contributions. There are currently many solutions on the market that are energy efficient, both technically and financially. The deployment of these solutions should be supported with as many resources as fundamental research on technological solutions. Clearly, technology must continue to evolve, but in today's society we need much more action around stakeholders'participation, who will ultimately decide whether or not to join the collective effort. This is certainly the main benefit of "action research" to promote the energy transition that really contributes, here and now, to increasing the production of renewable energies and reducing CO^2 emissions.

8.5. Checklist for getting started with the "Living Lab Integrative Process"

The Living Lab Integrative Process is explained step by step in the following checklist. The aim is to transmit the standardised method to professionals and researchers wanting to experiment it.

Figure 32. Living Lab Integrative Process

1. **Selecting a practice**

   Study the available data on your energy service. What are the practices of the actors that have a strong impact (positive or negative) on the efficiency of your energy service? Select between 1 and 3 practices (e.g., taking a bath instead of a shower, leaving windows open, changing the temperature set point, allocating charges to the residential surface...). Try defining the "roots" of the problem and not only the symptoms.

2. **Integrating stakeholders**

   Make a list of stakeholders who have influence over your energy service. Try to place them on the power/interest matrix (your own assumptions): (e.g., the commune's energy delegate, the building janitor, the end users, the financiers of the solution, the energy distributor...). (Eden & Ackermann 1998, in Bryson, 2004).

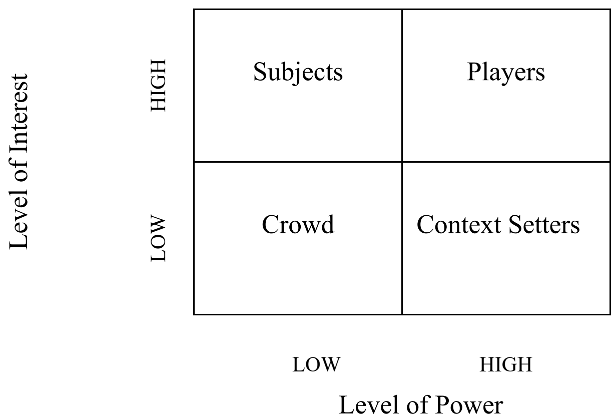

Figure 33. Power-Interest Matrix, adapted from Eden & Ackermann in Bryson 2004.

3. **Identifying the barriers**

   Interview the key players individually (box: Keep satisfied, Manage closely, and Keep informed). Are your assumptions true? What are the barriers and levers of action of these actors toward efficiency?

4. **Co-designing the solution**

   Then bring together the key players (e.g.: workshops, world cafés, BarCamps). Ensure that you invite the four types of actors: companies, public authorities, citizens/users, academics. Work toward developing a common vision and shared objectives for your energy service. Co-develop the solution WITH users, not FOR users (using design service, design thinking, crowdsourcing, etc.). Adapt your vocabulary to an audience with a low level of energy knowledge.

5. **Piloting an experiment**

   Test the co-designed solution in the field and not in the offices! Collect feedback to improve your energy service (interviews, ethnographies). Perform as many iterations as necessary without waiting for a final prototype (agile methods).

6. **Evaluating performance**

   Establish the measurement and verification plan before the pilot (e.g., IPMVP) and evaluate the results regularly. Triangulate the data to verify your conclusions (quantitative, qualitative, etc.).

7. **Communicating results and replication**

   Communicate the results of your project to all stakeholders and celebrate success with them (media communication, end-of-project event, etc.). Share your success to allow others to replicate it (open innovation, open science).

8.6 References of chapter 8

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Chapter 9

Discussion and conclusion of the thesis

This final chapter proposes an overall discussion of the thesis. It will be built on the findings of the seven preceding papers. The main theoretical, methodological and managerial contributions will be expressed. The overall conclusion will draw attention to the limits of this exploratory thesis and future researches. The role of the default rule will be presented and links with behavioural economics will be proposed.

9.1 Overall discussion: role of co-design toward energy performance

Today, we are at a turning point in the environmental sector and the next decade will be crucial for the climate and the welfare of human beings. Numerous scientific papers such as the recent IPCC Special Report *Global Warming of 1.5°C* (2018) demonstrate the massive impact human beings have on nature. This report, written by 91 researchers, also presents scenarios to mitigate the risks of climate change. It asks for *"**systems transition** unprecedented in terms of scale"*. The energy demand is at the heart of this transition toward decarbonisation. *"Mitigation options that reduce **energy demand** – largely through a switch to more energy efficient technologies and behaviours – have the largest positive impacts and smallest negative impacts on the SDGs"*[30] (larger than energy production). A new research in the journal *Nature Energy* emphases the need to work on energy demand to be able to reach the goal of 1.5°C warming (Grubler et al, 2018). The building sector represents 40% of energy consumption (EC, 2013). The thematic of energy efficiency in buildings is of particular interest toward this goal. The thesis goes in this direction in proposing **system change beyond behaviour change**, in focusing on **energy efficiency in the building sector** as the most impactful challenge today.

What is the role of marketing in the actual environmental situation? From the authors' perspective, the satisfaction of individual needs, without considering the impact on the environment and the wellness of future generation, has generated pressure on the ecosystems during the last century. From the beginning of the XXth century, and the birth of modern marketing[31], this discipline has had an important impact on the environment. It continues to do so when focusing on answering the short-term customers' needs (micro level) without considering the impact of products and services on the environment and on the wellbeing of society (macro level). We have defined in chapter 1 the notion of "social idea", an idea related to the **welfare of human beings**[32]. The new products and services developed by marketers today are not all based on "social ideas" and the impact on welfare of human beings is not the top priority of firms today. The welfare of their **target audience** may be of importance, but this assumption is not always true (marketing to encourage smoking, alcohol drinking, fast food…).

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[30] https://www.carbonbrief.org/in-depth-qa-ipccs-special-report-on-climate-change-at-one-point-five-c
[31] https://en.wikipedia.org/wiki/History_of_marketing
[32] https://www.merriam-webster.com/dictionary/social

This has led public opinion to a certain **mistrust of marketing**. Without trust, there is no openness or co-design process possible, as demonstrated in the Article 3. I used to be one of these marketers, in multinational companies after a university master's degree in management with a specialisation in marketing. Often, marketers are asked by their employers to focus on the increase of the turnover in order to satisfy short-term needs of consumers and shareholders. The wider long-term priorities and needs of the **different stakeholders** are rarely included in the design and operation of products and services. This is slowly changing today with the emergence and diffusion of "social marketing", "corporate social responsibility," "circular economy," "sharing economy" and more focus on ethics and sustainable development in general at a macro level. These concepts and courses did not even exist at the time I completed my master's degree in a leading business school. 15 years later, these courses have been developed, as in many other universities such as the University of Applied Science Western Switzerland and University of Lausanne.

In the quality department of companies, the story is somehow different and if we take the ISO norm 9'001 as an example. It urges enterprises to **take into account the views of all the stakeholders**, not only the customers and the shareholders. The core quality of products and services is central in diminishing the impact on the environment (SQS, 2015):

> *"ISO 9001:2015 is providing the basis for a sustainable and target oriented positioning of enterprises on the markets. Thus, chances and opportunities could be achieved and implemented as well as risks reduced. The demonstrably fulfilled* ***requirements*** *should lead to a development of* ***confidence*** *and a consolidation of image for customers and* ***stakeholders****."*

The third article of this thesis has been focused on the central concept of **trust**, linked with the notion of "**confidence**" mentioned in the ISO norm 9'0001. When opening the barriers of the enterprise to external ideas and perspectives, trust among the people inside and outside the company is an **essential component of the co-design process**.

The case of energy services (heating, lighting, ventilating…) is no different. For the past decade, the European energy market has been opening and competition between firms has increased. Utilities are under pressure, trying to combine the new legal requirements to encourage their customers in energy conservation practices and at the same time the urge to stabilise or, if possible, increase the turnover. New services are being developed, trying to combine these two apparently diverging objectives, as we can see in the smart meter market or the market of devices and apps to monitor and control the energy consumption. Consulting services are also more often provided to help customers reduce energy consumption and to increase the turnover of companies. The market of renewable energy technologies is also developing quickly, but maybe not enough to achieve the ambitious policy objectives of the European commission.

The missions of the Energy Living Lab are to support the development of renewable energies and increase energy efficiency. In a LL, four types of partners collaborate to co-design services: public authorities, private companies, researchers and citizen. This setting is called "*The quadruple helix*" (Arnkil et al, 2010). This openness to external contributions is not in the culture of every company. **Working with the willing and supporting actors first** is key to success of such participative methods. During the first crowdsourcing project in 2014, it was evident that the different stakeholders were not used to collaborate. The public authorities were seen as regulative rules developers, putting barriers for the companies to operate. The public authorities perceived the companies as entities led by profit and sale more than by social welfare. The association of citizen were somehow defiant about the co-design process. **Building trust among the actors** was the first objective of the LL manager, before beginning any service design activity. This idea of confronting point of views and allowing time and space to express it among stakeholders is shared by social marketing. As expressed by social marketing scholars:

> "*to harness the value of dissensus, not only* ***time*** *but also sufficient* ***space*** *must be given to the actors in the dissensus process*. […] *This will require social marketers to move beyond current exclusionary practices and* ***to create environments, whereby conflicts can be safely surfaced and shared priorities determined.****"* (Brennan, Previte, & Fry, 2016, p. 7)

LLs can provide this type of **inclusive and neutral environment, favouring dialogue** to co-design shared priorities and objectives together. Marketing has proved to be **a powerful tool** in developing new products and services and selling them on the market. This has transformed in the past twenty years due to the digitalisation of the economy and the growth of e-commerce; however, the basics are the same: product, price, place and promotion. The energy sector has been monopolistic for such a long time. The marketing culture is not as developed as in fast moving consumer goods (FMCG), but this is beginning to change. With **social marketing**, the tools proven successful in the FMCG are used in the pro-environmental domain as well and a worldwide community of social marketeers, grouped in the World Social Marketing Association federate the efforts and the exchange of knowledge. This discipline is evolving in the direction of LLs, integrating more stakeholders in the development of interventions.

The binomial approach of marketing with one company serving its target audience is slowly evolving to **open the barriers to the external world**. This evolution follows (slowly) the development of Open Innovation, from the first mention by Chesbrough in 2006. They are adapted to a change in the objectives: answering the **needs of multiple stakeholders** and not just customers and shareholders. It is not only company-customers or a public-private perspective but also a wider **ecosystem of actors** to be included in the OI process to develop shared priorities and agendas. Social marketing scholars such as Brennan et al (2016, p.5) express it as a "*marketing myopia*" to concentrate only on the target audience. They ask to enlarge the perspective: *«Social marketers need to broaden their view of consumption and culture to take into consideration* ***a wider set of stakeholders*** *who are and could be involved in a social change strategy.*

Integrating the different stakeholders in an ecosystem of actors needs **innovation intermediaries to orchestrate the process**. A neutral, **trusted** actor, in a public private people partnership (PPPP), with social marketing and/or social innovation competences in order to build a common vision among the actors, guides the innovation process, provides the tools and measures the results of the intervention on the socio-technical system. LLs have been tested in this thesis as this central **innovation intermediary** facilitating the co-design process of energy efficiency interventions. Numerous examples of Living Labs are known in different domains such as health or ICT; however, few examples of Living Labs exist in the energy sector. Hence the creation of the Energy Living Lab to test the transferability of Living Labs approaches in the energy field. LL as innovation intermediary provides tools developed by the community[33]: part of them are available on this website: https://www.u4iot.eu/

These tools and best practices are shared during the OpenLivingLab Days annual conference (Energy Living Lab has co-organised this conference in Geneva in 2018): https://openlivinglabdays.com/. The proceedings of the conference are also provided to share the knowledge among researchers and practitioners.

As a pluridisciplinary community, the LLs use **numerous methods and tools**. The article from Pallot et al at the first LL summer school in Paris in 2010 gives an overview of *The Living Lab Research Landscape* which is very diverse and pluridisciplinary. During its four years of existence, the Energy Living Lab has tested multiple tools developed by different disciplines such as "the business model canvas" from management[34] in Article 1 (Osterwalder and Pigneur, 2010), the "crowdsourcing platform" www.i-brain.ch from innovation management in Article 3, "the persona" from design thinking[35] (Miaskiewicz and Kozar, 2011) in Article 5, "the blueprint" from service design[36] presented in another article from the author at OpenLivingLabDays 2017 (Papilloud et al, 2017). Depending on the phase of the co-design, different tools are used.

The Living Lab community can be enriched by the Social Marketing community in providing nearly 50 years of experience, tools, best practices from the first mention of social marketing by the "guru of marketing", Kotler in 1971. Social marketing works on the same sectors such as health, environment, food, tourism… With the common vision: **the welfare of human beings.** The notion of "social marketing" came really late in this thesis but the visions, goals, processes, tools are similar as in Living Labs. These two communities mixing researchers and practitioners have strong common characteristics and would gain in sharing their knowledge.

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[33] https://www.u4iot.eu/
[34] https://strategyzer.com/canvas/business-model-canvas
[35] https://dschool.stanford.edu/resources/design-thinking-bootleg
[36] http://www.servicedesigntools.org/tools/35

This thesis also answers a common question from engineers and architects: **are the consumers ready to give ideas for energy conservation measures? Do these ideas generate value?** the energy literacy is very low in the general population. Even the inhabitants of a sustainable neighbourhood, with a positive attitude regarding the environmental challenges do not know much about energy, as confirmed in this research. Energy is considered a technical domain and only engineers or architects seem to have their word when developing energy services (heating, lighting, hot water heating, ventilating…), with a paternalistic perspective. Engineers and architects have their separated expert fields of competences as well and numerous examples show the **lack of synergies among them**, resulting in underperformance in complex low consumption buildings such as the case of the ventilating system's regulation in the studied neighbourhood. Specialists in ventilation and air conditioning (VAC) are not specialists in electricity or automation. As the technical complexity of low consumption buildings increases, collaboration and discussion among the different specialists is crucial in order to operate the building correctly and avoid technical performance gaps. This **requires openness to understand each other's work** and to generate synergies and increase the overall energy performance of the building. It also requires **common objectives and priorities** on this theme.

When asked about the price of kilowatt/hours, most of the consumers cannot answer, disqualifying interventions only based on price. We have interviewed numerous actors face to face during the different phases of this thesis, over five years. Nearly all of them know about sustainable development, the challenges we face today and in the future, which practices have an impact on energy consumption. **Information is not missing** in the different contexts we have studied, disqualifying interventions only based on information and communication, which are still the main tools used by energy agencies to involve the stakeholders, with communication intensive campaigns.

Most of the stakeholders we have met are **willing to collaborate** to co-design solutions to the challenges we face. Spontaneously, they thank the researchers for asking questions because they are surprised their view would have a value. Before the first question from the researchers, participants apologize for not being able to answer all the questions, disqualifying their knowledge as non-specialists. However, co-design with numerous stakeholders needs a facilitator, **an orchestrator** who asks them questions, who puts this question of energy services at the top of their mind, who reassure them on their competences to answer the question in order to **build a common objective together**, **direct the co-design process** and **follow the progress toward the goal**. Otherwise, in our society where people feel they have less time, and the stress level increases, other priorities will take the top of mind position.

This is what we have seen in the second article: the variable "satisfaction to live in a sustainable neighbourhood" is not strongly linked to energy services but to **interpersonal relationships in the neighbourhood** (real "social networks"). This is a question of priorities and importance of thematics. By studying the overall satisfaction in the neighbourhood and not only satisfaction toward energy services, we can compare the importance of each item with a correlation study. Energy is not central to the satisfaction of the inhabitants when the core quality of the energy service is good. In addition, we have measured that a service, by definition, is intangible and if the core quality of the service is good, the consumers do not link it with satisfaction of living in the neighbourhood. The functioning energy service is taken for granted. **There is no need behind energy conservation** for the users if the system is working properly. On the contrary, when the core quality of the service is low, such as a problem with the heating system, the energy service becomes tangible and dissatisfaction is more strongly linked to the perceived bad quality. This is a problem of **asymmetry of perceptions**: bad core quality is perceived; good core quality is not perceived. The touchpoint with a bad service quality can be used by energy planners to bring the energy top of mind and **push the actors toward action**. As design thinking proposes: *"Bias Toward Action. Design thinking is a misnomer;* ***it is more about doing than thinking****. Bias toward doing and making over thinking and meeting." (*Both & Baggereor, 2010), LL community shares the same mindset of "doing" and use as well D School Bootcamp Bootleg. The "makers" initiatives are also really close to the LL movement. An example of how makers could contribute is proposed in the Article 3 with the Lorraine Fab Living Lab.

Some national research initiatives such as in the PNR71 propose an energy blackout during night parties in a neighbourhood to help the people **experience the benefits (value) of energy services by the absence of energy services**. Another example is the Energy Living Lab initiative in Rwanda where **we co-design renewable energy services with the stakeholders**. The benefit from energy services is clear: before the Living Lab, there was no energy, no hot water, and no light to work at night in the villages. After the intervention, renewable energy services were provided, and the value of energy was directly salient, changing the practices.

Experiential marketing is again recommended. One of the students participating in the Rwanda project wanted to explain to his colleagues who stayed in Switzerland his role in Rwanda. He made them experience by themselves by turning off the light in the classroom. He then asked them to try reading their book. Of course, it was impossible in the dark. He then put the light on again and told them: "This is how the children study in Rwanda at night". By bringing the energy service "lighting" in Rwanda, the children could work at night in their villages. There is a need behind "lighting" in Rwanda. There is no need behind "lighting" in Switzerland because it is considered as a "by default energy service". **Experiential marketing** could help make the energy service more tangible, even if core quality is good to make the stakeholders experience the value of the energy services.

Studying energy services is always linked to a period of time and a place, as well as cultural values associated with it such as the expected comfort level. **The role of the context of the social practice is central**. In Spain, for instance, where the author has spent her scientific leave, it is normal not to have a heating system in the apartment. People moving into a new apartment ask about the presence or absence of a heating system, which will never be the case in Switzerland as the social norm, by default, is to have a heating system. Energy services are **taken for granted** and the absence of energy services or a perceived poor quality of services is more salient. The study of **salient attributes of the service** is to help better develop energy conservation interventions. This highlights the value of **working on the cognitive norms** of the socio-technical system defined by Scott (in Geel, 2004) in Table 12. Indeed, they are taken for granted in a value system linked to the context of use. **What are the priorities of the actors? What are their own perspectives on energy services?** If diverging priorities appear, **who has the power to impose his priority?** The planned intervention needs to consider the pre-existing cognitive norms of the different actors. Hence the need to coordinate the ecosystem of actors and to **interview each of them individually** before putting them together in a workshop: to collect each actor's perspective on the subject. In the Energy Living Lab, the method is always to begin with a face to face interview with each actor involved in the co-design. This helps collect individual subjective perceptions and prepare the moderation of future co-design workshops, whatever the type of activity, which is planned.

	Cognitive
Examples	**Priorities**, problem agendas, beliefs, bodies of knowledge (paradigms), models of reality, categories, classifications, jargon/language, search heuristics
Basis of compliance	**Taken for granted**
Logic	Orthodoxy (shared ideas, concepts)
Basis of legitimacy	Culturally supported, conceptually correct

Table 10. Cognitive rule, adapted from Scott in Geels (2004).

Does that mean stakeholders are not willing to collaborate and co-design energy efficiency interventions in the building sector? Not at all. People participating in surveys, face-to-face interviews, workshops, ethnographic studies for five years were **positive about having their say on the developed solution**. For instance, we could not stop them when playing with personas of different energy stakeholders in a gamification activity in the neighborhood. They were themselves surprised by the interest of other participants. When we compare on a matrix the perceived level of self-interest versus self-power, the declared level of self-interest is always high. The problem is on the perceived level of control: stakeholders in the different case studies do not think they have the power to solve the difficult challenges of energy performance. They do not feel they have the legitimacy and the competencies to solve problems. Even in management positions, they give the power to another actor. **They need to be "empowered" and reassured to co-design the service by an external innovation agent, the Energy Living Lab in this case.**

The danger of this research is to stay at a conceptual level and not to develop the artefacts at the end of the different projects. Co-design processes increase the level of expectations of the different stakeholders. If we ask the question about what could be done differently to decrease energy consumption, the stakeholders propose ideas and are waiting for an implementation of what has been proposed and selected as a good idea. The risk is to lose the trust among the different actors if no action is undertaken after such researches. The planned and regular communication in the ecosystem of actors is also crucial. This is the reason why we will continue with a quasi-experiment in the studied low consumption buildings.

9.2 Main contributions: theoretical, managerial, methodological

In this section, we will describe the different types of contributions: (1) theoretical, (2) methodological as well as (3) managerial. As often in marketing, the three contributions are expected.

Theoretical contribution

LLs is a recent phenomenon and inconsistent definitions of the phenomena co-exist. The author proposes her own definition to clarify what is considered as a LL in this thesis:

> *A Living Lab is an innovation intermediary, which orchestrates an ecosystem of actors in a specific region. Its goal is to co-design product and services, on an iterative way, with key stakeholders in a public private people partnership and in a real-life setting. One of the outcomes of this co-design process is the co-creation of social value (benefit). To achieve its objectives, the Living Lab mobilises existing innovation tools and methods or develop new ones.*

This pluridisciplinary research on energy performance in low consumption buildings is nourished by a large amount of literature from different disciplines mainly: engineering, marketing, economics. The thematic has already been studied for decades but decreasing energy consumption in the low consumption buildings is still challenging. Interventions only based on price incentives are shown as underperforming, as consumers do not know the price of energy and even if they know it, the price of energy is too low at the moment and the return time too long to motivate a change in consumption practices. Interventions based on informing the consumers aren't enough, either. Most of the consumers are aware of the good practices in terms of energy conservation.

We propose to combine CBSM with LL methods to empower the stakeholders and co-design interventions together. Co-creation is a theoretical framework widely studied in the marketing discipline but not in the energy field. This thesis proposes a new process to co-design energy conservation interventions with the stakeholders.

In the last paper of the thesis, a new conceptual model is proposed to deepen the understanding of the energy performance gap and a particular focus is on the "social performance gap" as shown in Figure 34:

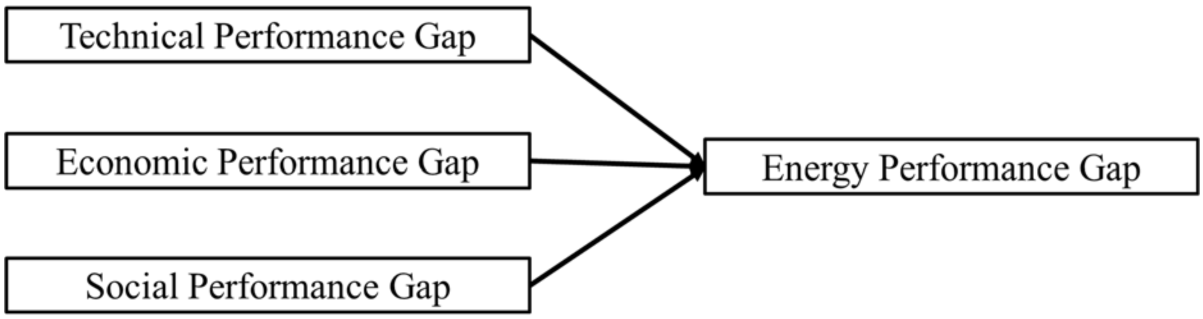

Figure 34. Conceptual Model of Energy Performance Gap.

The notion of "**perceived service quality**" is central to understand the "social performance gap" and the impact of practices on energy consumption is increasing in low consumption buildings where recent "green technologies" have been deployed in buildings. The theoretical model encourages researchers in engineering and architecture to take into account the role played by "occupants" of the buildings on energy performance gap and provides a quantitative method to measure what we call the "**social performance gap**." The importance/performance matrix Martilla (1977) of different energy services has been used to operationalise the "social performance gap" in the studied neighbourhood. Important discrepancies have been illustrated in article 6. Other methods could be used such as SERVQUAL measuring service quality if there is only one energy service to measure (Parasuraman et al., 1988).

Methodological contribution

The method to study energy performance is as crucial as the results of a particular case study. In the environmental sector, there is an attitude-behaviour gap mentioned by numerous articles such as "*Mind the gap*" from Kollmuss and Agyeman (2002). Participants in enquiries answer on attitudinal questions such as "Do you switch the lights off when you leave a room?" Who would like to be perceived as a person that does not care about the environmental challenges our society faces today? Numerous studies have shown a discrepancy between what the people say in quantitative enquiries and what they actually do in their home.

Why are researchers continuing to use enquiries, collecting attitudes as a proxy for behaviours? This is a mystery, as the attitude-behaviour gap is known for already 15 years. Maybe because it requires fewer financial resources and is quicker to collect data. Why are energy agencies financing researches based on attitudes as a proxy for behaviours? This is also a mystery. An explanation could be that a positivist mindset encourages them to favour quantitative hypothesis-testing and this is achieved mainly through enquiries. A good example of this positivist mindset, studying the same thematic of energy performance gap in residential area, concentrated on the same energy services (heating) with the same wording of "Living Lab" is described in a paper from Eon, Morrison and Byrne (2018). They have not integrated co-design process. They have collected data on attitudes toward energy consumption. They have understood Living Labs as "testbeds" to learn about the social practices of inhabitants and have studied the technical artefacts. For the author, without co-design, this experiment is not a LL. It does not meet ENoLL criteria to obtain the LL label. Observing practices without co-designing energy services is not in our understanding a LL.

How does one study the energy performance differently? **By combining observation and participation methods** (ethnography, qualitative interviews, workshops, etc). We propose to collect only socio-demographic data through quantitative enquiries to be able to understand who is "hiding" behind the energy consumptions curves and develop typologies of users. We only collect data on attitudes to confront them with data from smart meters and better understand the attitude-behaviour gap, in terms of amplitude of the gap. What is proposed in this paper is different: it is "**extreme citizen science**." With a constructivist perspective, we co-design the research and the artefacts with the stakeholders in a LL setting, using social marketing and co-design tools. **The applied research is mostly in situ** and follows a standardized process. The role of the researcher in this participative transformative research changes to a facilitator, an orchestrator. This is clearly not an hypothetico-deductive perspective as often seen in the energy field. We have only used hypothesis-testing in this thesis when we wanted to measure relations between variables such as in the first article or measurements of impact, such as the quasi-experiment that will follow.

In a pluridisciplinary context, the researchers coming from different disciplines influence each other with their methods and paradigms, strengthening the research projects. Each researcher brings with him his own lenses and research paradigm, which need to be combined. Wacker proposes to triangulate the data collection and to develop and test theories with multiple procedures (1998). In this thesis, we have applied the following procedures: **analytical conceptual, statistical sampling and case studies.** The **experimental design** will follow.

Social marketing is also evolving in the direction of integrating different types of actors, not merely the company and their customers. However, the dominant marketing paradigm with the focus on the consumers is putting up barriers toward this evolution. A new paradigm is needed to study the complex building systems at the nexus of production and consumption, the default rules in force in the ST-system, actors and technical artefacts. What we propose contributes to this shift.

Managerial contribution

The two researches "Energy Living Lab pilot" project and "UserGap" project have been developed in partnership with researchers, economic actors, citizens and public authorities. Our projects have their roots in the Living Lab approach of integrating the quadruple helix principles in an ecosystem of actors; co-design tools are deployed to empower the different stakeholders to build a common vision. We recommend to the architects and engineers developing plans for new low consumption buildings or neighbourhoods to take into account, **as early as possible in the design process**, the perspective and input from a wide variety of actors, including future inhabitants. To facilitate the launch of a project in a LL setting, we propose the following process illustrated in Figure 35:

Figure 35. Living Lab Integrative Process

The "**Living Lab Integrative Process**" (**LLIP**) is recommended to energy planner, constructors, utilities, public authorities. As expressed in this thesis, the focus of this process is not on "behaviour change" as in social marketing but on "**system change**", acting on the technical artefacts, the rules and the actors of the system. We have proposed at the end of chapter 8 a **checklist to test the Living Lab Integrative Process**.

Professionals as well as public authorities or researchers can test by themselves the interest and results of the process in a simple and intutitive approach.

In this thesis, the different energy services were at the center of the analysis (heating, lighting, ventilating…). Priorities are decided based on evidences and statistics, not feelings. In the studied neighborhood, there was a clear overconsumption of heat, 30% above the value recommended by the standard SIA 380/1 and a disfunction on the ventilating system. We could as well have focused on electricity consumption from the different home appliances. Social marketing encourages to target a specific behaviour, here we propose to target a specific practice, based on evidences of EPG.

In the proposed "**Living Lab Integrative Process**", the focus is still on understanding the barriers toward a pro-environmental practice, as proposed by CBMS. To overcome the paternalistic view adopted often by professional energy planner, co-design has been integrated in the process. Both processes encourage planners to pilot an intervention on a small scale before enlarging the program to a wider audience. Evaluation is key in both processes, thus social marketing benefit from 50 years of experience on how to measure the impact of a program. In LLs and in OI, the evaluation phase is still a challenge after 10 years of existence. Professor Jeff French teaches how to measure impact of a plan to the social marketing community and his book can be of great help for the newcomers in social marketing discipline (French & Gordon, 2015).

When planning the development of a new sustainable neighbourhood, the author has been asked by different constructors how to involve future inhabitants. In the design phase, the pre-occupancy phase, inhabitants are often not known well in advance. We stand that even if the citizen included in the co-design activity will not be the future "occupants," a bottom-up insight is crucial. A **feedforward** loop could help reduce the operational gap in future contexts, as illustrated in Figure 36:

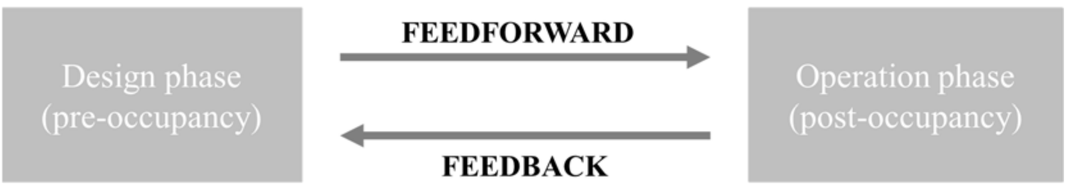

Figure 36. Iterative loops between design and operation.

For an example of the use of feedforward, the method has been tested in the pharmaceutical company by Deborah Glassey-Previdoli (2018) in a master thesis. **A feedback loop should as well be planned** in existing buildings and neighbourhoods of the same constructor. This could take different forms such as an idea box, a virtual feedback collecting platform, a workshop with stakeholders and a Living Lab initiative. Common logic from "the crowd" could be beneficial such as in the crowdsourcing process we have tested in Article 3 with the support of the technological platform www.i-brain.ch. The cost of the different measures needs to be considered and for a company developing multiple projects, a knowledge management system could be of help, one pilot project nourishing multiple construction projects.

In terms of national construction standards, the literature encourages testing the different hypotheses in the standards to see the closeness to the actual energy consumption of buildings measured by smart meters. What are the assumptions made on "social practices" in the standards? In our case, it was labelled as "**standard use of energy in the building**" and contained numerous assumptions on social practices. The standards have been written by specialists from the building sector and we recommend integrating **specialists from social sciences** as well as to write the standards and take into account the social dimension of energy performance. Too high objectives and repeated energy performance gaps could be seen as "green washing" and the label based on the standards could **lose the trust of the stakeholders**.

In terms of measurement of actual consumption versus the standards, dynamic simulation integrating actual data could help reduce the performance gap but as a non-specialist in this domain, the author will not elaborate further. More details are proposed in Burmann et al. (2014) or in the recent article from our UserGap research consortium (Paddey et al, 2018).

The research team recommends SFOE and other national energy agencies to **better integrate social science researches and technology-focused researches in transdisciplinary funded programs**. Separating them does not allow one discipline to be nourished by another. If the goal is to work on the socio-technical system, to act on the rules, the actors and the technical artefacts, a transdisciplinary approach is requested. More pluridisciplinary and transdisciplinary research is needed in the energy field. It is a matter of openness and trust to other disciplines. It is more about soft skills than hard skills and is difficult to promote. I have had the chance to live in such an open and supportive research environment during this thesis. The example of the SCCERs is a good one; of course, we need specialists in energy efficiency or in wind power.

However, to increase the social performance of the different products, services and business models, we also need integrated transdisciplinary applied researches. Educating the researchers to OI and LL principles could also be an alternative for them to test the methods in their own research projects.

9.3 Overall conclusions of the thesis: back to the research questions

The goal of this overall conclusion is to come back to the research questions: “Is the co-design method used in Living Labs transferable to the energy sector? How to engage the key stakeholders in the co-design process of an energy conservation plan? What would be the impact on energy performance gap? The main questions have been divided in sub-questions or objectives addressed in the five scientific papers plus two vulgarisation papers for professionals. The main results are presented and interpreted below. As summary of the different sub-questions is proposed. Then, the main research questions of the thesis are addressed, with the findings coming from the five scientific articles.

Article 1: What defines a Living Lab concretely? What are the common characteristics of Living Labs? How to evaluate LLs? Is it adapted in the energy sector?

This article has proposed a review of the evaluation process to become an adherent member of ENoLL. The business model canvas has been used to map the different evaluation criteria (Osterwalder and Pigneur, 2010). The findings demonstrate three missing evaluation criteria: (1) who is the target customer: if we are all partners in the PPPP, who is our “customer”?, (2) what is the revenue stream: if different level of maturity as an innovation intermediary co-exist, different potential revenue streams co-exist as well among the members, and (3) what would be the recommended cost structure, closely linked to the revenue stream. Table 12 propose a typology of innovation intermediates. The different LLs are distributed among the different categories of the typology, depending on their **level of maturity**. Some LLs have a strong infrastructure such as an innovation incubator. Other LLs do not have infrastructure and provide innovation services such as innovation traders. ENoLL could support the development of the maturity, from innovation traders toward innovation mediators. With some exceptions in the network, LL begins with step 2 or 3 and increase toward innovation mediator over the time.

Type of innovation intermediary	Definition
1) Innovation consultants	Provide innovation services, relying on internal sources of knowledge, to solve specific innovation problems or requests.
2) Innovation traders	Screen and provide access to a large amount of external ideas and innovations, relying on a platform of innovation solvers, to facilitate the identification of potential scientific and business-oriented solutions.
3) Innovation incubators	Provide infrastructures to facilitate the internal exchange of ideas and knowledge among firms searching to conduct science, technology or business activities.
4) Innovation mediators	Provide infrastructures to facilitate the use of external ideas and knowledge coming from users, entrepreneurs, R&D institutes to established firms searching to conduct science, technology and business opportunities.

Table 11. Typology of innovation intermediaries, adapted from Lopez-Vega and Vanhaverbeke (2009).

The LL process has been applied to the energy sector with the case study of the launch of the Energy Living Lab. It has demonstrated the transferability of the method in the energy sector. After this introductory question on the phenomena of LLs, the focus is on energy services to better understand the perceptions of the inhabitants.

Article 2: How are the energy services perceived by consumers in low consumption buildings?

Why is this question important? Because the socio-technical system is composed of rules, artefacts and actors interacting (Geels, 2004). Before acting on the ST-system with an intervention to change it, understanding the system and the interaction between the three components is essential. This quantitative enquiry has achieved the goal of better understanding the interrelation between the economic, the technic and the social part of the energy performance gap.

This article has demonstrated that the **link between energy services and the overall satisfaction of living in the neighbourhood is low**. The energy services are closely related to dissatisfaction in the case of underperforming services such as a failure of the ventilation system. The focus of the energy conservation intervention could be to make energy services more tangible, especially in the case of qualitative energy services. Interventions could also be based on the absence of energy services for a period such as experiencing “blackouts.”

Experiential marketing could be of help to bring energy conservation practices top of mind. It is linked with the service design science: logistical salient attributes are essential for the service to operate but they are not perceived by the users. The emotional salient attributes are perceived and create value. Energy services such as heating, lighting, are mainly composed of logistic salient attributes. To co-design an intervention on the system, **new emotional salient attributes need to be integrated**. This could be done using colors for instance, which could tangibilize the service and create an emotion during the social practice. Experiential marketing could be of great help to develop new salient attributes. In the neighbourhood, the survey and qualitative interviews discovered dysfunctioning energy services and an energy performance gap of 30% on heating. Inhabitants where not satisfied with the temperature in the neighbourhood, blocked at 21 degree. An energy efficiency plan will be designed to reduce the performance gap. To avoid a paternalistic approach of one actor developing the plan, a co-design approach is tested with key stakeholders. It is the subject of the next article. What is the element supporting co-design in the energy field?

Article 3 What is the role of trust in a co-design process?
How to establish and maintain relationships of trust among the stakeholders?

Trust is a **central element of OI**. Without trust, the co-design process in LLs is not optimal. When co-designing a new product or service, the result cannot be seen until the end of the process. Contract among the partners are difficult to develop, due to variables not anticipated at the beginning of the process. Contract developing is costly and time consuming, as described in Article 3. In many cases, it is not possible to brand an idea and the question of the Intellectual Property Right (IPR) is central and sensitive in OI processes. Trust among the partners in the PPPP is essential to create an environment where the actors are reassured the benefit (value) of the innovation process will be shared and will not only go to one actor. The LL manager has a central role to play to develop trust among the partners. Universities, cities, regional authorities developing **LL initiatives often play the role of this trusted coordinator**. The innovation intermediate is key for the success of the process.

The Co-coon Matrix has been proposed to facilitate the development of trust in a co-design process. As demonstrated in the two use cases, some important steps of trust creation and technologies to support trust during the process are key for success.

Article 3 is based on two case studies, one on these is the case of the Energy Living Lab crowdsourcing challenge. Below are the research questions addressed by this case study. What is tested is the co-design process in the energy field. Crowdsourcing is used as the innovation tool to let tacit knowledge emerge from the participants.

Are consumers ready to co-design energy conservation interventions?
Do these ideas generate value?

Consumers are ready to give ideas about energy conservation interventions. A diverse community is needed in order to increase the quality of ideas; integrating students and customers is a good way to diversify the output. Different platforms are also needed, not only an online crowdsourcing platform but also direct contacts with stakeholders. The “not selected here syndrome” appeared and demonstrated the importance of the idea selection process. Proposing two different juries, one from the company and the other from external experts, was not a good process in terms of managerial implication, as it stopped the OI process.

Energy is still a sector with a closed innovation culture (a culture not used to integrate consumers in product and services development). It will take time to change this culture. The utility that provides energy as well as television and internet evolve in a more competitive environment and seems to be closer to their customers and more open to integrating them in an OI process. Crowdsourcing is mostly based on a company developing a challenge and the “crowd” answering to the challenge. One step further can be achieved if the stakeholders (quadruple helix) co-design the challenge with the public or private company. This is what the LLs propose and it has been tested in the article 4.

Article 4 **How are different stakeholders integrated in the co-design of an energy conservation intervention**?

The Energy Living Lab method has been tested in the case of the co-design of a BEMS. The ELL proposes a standard process to integrate the stakeholders in a co-design process: The ***Living Lab Integrative Process***. It begins by understanding the social practices linked to energy consumption. A first diagnostic of these practices is made by a team of engineers, marketers and economists. The focus will be on the practice causing the higher EPG. After this diagnostic has been established, the key stakeholders are analysed with a power/interest matrix and integrated in the development of the EE plan. Building a common vision on the challenge is important to co-design the intervention.

In the studied low consumption building, the level of perceived control seems to cause problems as no actors take the ownership of the energy challenge. The dynamic view of the power/interest matrix is interesting, from the first researchers' hypotheses, to the perceived control and self-interest and the relative perceived level of interest and control of other actors. Understanding the social dynamics in the ecosystem of actors is key. Building a shared vision with all the stakeholders is important in bringing energy top of mind. A standard process helps to co-design new energy services. The EPG seems to come from technical as well as economic variables but the social dimension of energy consumption has not been integrated in the analysis, in the different existing models of EPG. The last article proposes to elaborate further this ***Social Performance Gap***.

Article 5 Is there a "social performance gap" in energy services? How is it measured?

The social dimension of the energy performance gap has been explored. A model is proposed to better understand the gap. There is a discrepancy between the expectations of the users and the perceive service quality of the energy services. This gap is expressed by the notion of satisfaction toward energy services. The SERVQUAL method could be one of the potential measures of the "social performance gap". This model measure with a multi-dimensional standard questionnaire the quality of the service. The SERVQUAL model is based on 44 questions for each energy service to assess. In the studied neighbourhood, different energy services are analysed such as heating, lighting, washing clothes… The SERVQUAL model would generate operational issues due to the length of the questionnaire. The importance/performance matrix has been tested instead for its simplicity and operationalisation. The matrix has been applied in the low consumption buildings of the sustainable neighbourhood under study. The results confirm the technical performance gap: there is a dysfunction in the ventilation system generating a social performance gap: inhabitants perceive the dysfunction and are not satisfied with the service. The energy performance gap is too often analyzed in the technical dimension and the economic dimension without taking the social dimension into consideration. The proposed conceptual model integrates the three dimensions in one model and proposes methods to operationalize it quantitatively.

This last article has demonstrated the importance to consider and to measure the social dimension of energy to reduce the EPG. An intervention co-designed with the stakeholders could help reduce this gap. Coming back to the main research questions, a summary of the findings is proposed below.

The main research questions of the thesis are the following:

Is the co-design method used in Living Labs transferable to the energy sector? How to engage the key stakeholders in the co-design process of an energy conservation plan?

What would be the impact on energy performance gap?

The Energy Living Lab pilot project has demonstrated the interest of using the LL method in the energy field. Yes, the method can be used in this field as well. The stakeholders, with a low energy literacy need more support in the co-design process and online platform do not suffice to manage the process. Face-to-face innovation tools give better results such as the game developed based on personas in this project. The importance of involving the stakeholders from the beginning of the challenge definition, the "fuzzy front end" is central. Too many projects integrate the stakeholders later in the design when important decisions have already been taken. ELL propose a standard process to integrate the stakeholders, the **Living Lab Integrative Process** and a **checklist** to apply the method. It permits to structure the co-design process. Learning from CBSM have been integrated in this process as both methods are close. Social marketing emphasise the importance of measuring the effect of the intervention, it is no different in the energy field and the smart meters and other types of sensors facilitate the observation of consumption patterns. To be able to measure the impact of the co-design process, a quasi-experiment will be done in the sustainable neighbourhood, proposing to test the co-designed energy conservation plan in situ.

9.4 Limits: exploratory, in Switzerland, in low consumption buildings

This section describes the limits of the thesis and the external and internal validity of the research. First, we study the **external validity**: "*The extent to which the research results from a particular study are generalizable to all relevant contexts*." (Saunders, Lewis, & Thornhill, 2016, p. 716). This research is based on a sequential multi-method. The research design and process are well described but not easy to reproduce. Two of the articles use the case study methods for exploration purposes. They are not intended to be generalized. The first paper is based on a quantitative enquiry that could be generalized; however, the context of all the research is specific: energy conservation in low consumption buildings. One cannot transpose it directly to the high consumption buildings. The field work has been done in Switzerland and the political, economic and cultural context does not permit generalizing it to other contexts. This exploratory work will be followed by a quasi-experiment in the studied sustainable neighbourhood to be able to measure the impact of the co-design of the energy conservation intervention.

Then, we would like to focus on **internal validity**: *"Extent to which findings can be attributed to interventions rather than any flaws in your research design."* (Saunders, Lewis, & Thornhill, 2016, p. 718). This thesis is based on longitudinal studies in situ in different contexts. The triangulation of data coming from different contexts and methods reinforces the internal validity of the findings. Using low consumption buildings as LLs permits the generation of qualitative data from interviews, participative observation and workshops. This immersion in the field increases the internal validity. In the following quasi-experiment, close attention will be given to the independent variables influencing energy consumption, such as weather. Econometric models will be used to control the external variables not linked to the energy conservation interventions. This study is also limited to the allocated resources. Pluridisciplinary competences need a longer adaptation time to understand the different paradigms and methods used. A common vocabulary is also necessary. In terms of access to data, it is really complicated to obtain consumption data, with the granularity necessary to perform the econometric analyses. Respect of privacy is central and has sometimes diminished the quantity of data available. The financial resources are also key to performing a research over a five-year period with a team of specialized researchers. Longitudinal in situ experiments require more financial resources than enquiries.

9.5 Future researches: role of the context and default settings

In this section, the direction for future researches will be drawn. The ELL will continue to provide applied researches and consultancy services on the theme of energy conservation interventions. The pluridisciplinarity could be further enlarged to other disciplines to obtain different perspectives on the complex system such as systemic, operational management, sociology, social psychology, etc. The next phase of the "UserGap" project will be to implement the co-designed energy conservation intervention in the studied sustainable neighbourhood to measure the impact of co-design on energy conservation and on social performance gap. An importance/performance matrix will be performed to prioritize the investments in the studied neighbourhood. Econometric analyses will take place, directed by specialists in this field, using the stochastic frontier analysis.

We proposed to integrate the learnings from Sunstein on "*the default rule vs active choice*" (2017), as well. We would like to understand when it is better to automatize the low consumption buildings with BEMS for instance and when it is better to empower the stakeholders with interventions such as the LL initiative. It could be placed on a continuum as proposed by Bryson in his article "*What to do when stakeholders matter:*" (1) Inform, (2) Consult, (3) Involve, (4) Collaborate, and (5) Empower (2004, p. 33). Opposing default rules and active choices is not mandatory. We propose to **co-design the default rules with the stakeholders** to counteract the paternalistic decision of one actor, such as one engineer, one architect and one company, on the default rules. Often, interventions based on active choices do have a lower penetration rate in the population. The default rules seem to increase the penetration rate among the population (Sunsteins, 2017). The active choice must often be renewed as, for example, when working on energy consumption routines. The risk is the non-perpetuation of the pro-environmental choice.

The typology of rules: "regulative, normative, cognitive" proposed by Scott (1995, p. 35&52) and cited by Geels (2004) is of interest in understanding the different types of default rules in the socio-technical system. Energy labels can also be seen as normative rules and as influencing cognitive rules, as well. The building system is complex, composed of rules, actors and technical artefacts (Geels, 2004). Understanding the tacit default setting is key to understanding the system and to act on it with a transformative intervention, a transition from one system to another.

9.6 References of chapter 9

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