Building 2050 Research program

smart
living
lab

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1 Genesis and goals of the program

The Cardinal brewery bottled its last beer in 2011 in Fribourg. In order to revitalize this postindustrial urban area, the Canton and the city of Fribourg decided to transform the site into an innovation quarter (a technology and innovation park), called blueFACTORY. Many technological platforms will be developed, including the smart living lab, a joint project between EPFL, EIA-FR and UNIFR.

The smart living lab project is born. The main goal of this project is to create a center of national and international reach specialized in the built environment of the future. To carry out this vision, five types of activities are envisaged:
1) Basic and applied research
2) Development and transfer of concepts and technologies
3) Demonstrators and pilot facilities
4) Post-graduate and continuing education
5) Networking

The vision of the smart living lab project is to create, in the heart of the blueFACTORY, a living and working space ahead of its time – i.e., the building itself - housing an interdisciplinary, inter-institutional center of excellence in the field of innovative concepts and technologies linked to the built environment – i.e., the contents of the building.[1]

The building will, therefore, have to be in the forefront of the current practices, and will be an experimental support center for the future research teams it will house.

The exceptional nature of the smart living lab project justifies the setting up of a preliminary research program, whose first objective is to define the scientific terms of reference of the performance requirements and how to integrate them to the construction project.
The expected gross floor area for the smart living lab is around 4,000 m² and divided as follow:

- Offices : 86 workstation / 950 m² net floor area (NFA)
- Experiment hall / 600 m² NFA
- Meeting, training and seminar rooms / 150 m² NFA
- Housing / 1000 m² NFA

A possible future extension of 50% of the smart living lab has to be taken into account.
The Building 2050 program consists of three main objectives, which correspond to three successive stages.

Defining the scientific concept
The main objective is the definition of a scientific framework that anticipates the performance level and the possible technical approaches to construct a building responding to the outlook 2050 challenges.

Translating the concept into an operational program
These requirements will then have to match the operational program for the conception and construction of the smart living lab, thus allowing the transition between applied sciences and operational program. In order to achieve this, an experimental phase is envisaged. It will allow the program to make the technical, economic and legal aspects reliable.

[1] EPFL | UniFR | EIA, « smart living lab, Summary document, Version 6 », février 2014.

The operational program will integrate the results of the research program by means of:

- Obligations to implement technical solutions
- Obligations to achieve performances
- Recommendations

Enhancing the value of the research program

All the work performed, will be enhanced all throughout the program by scientific and professional publications.

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2 Research assumptions

To specify the fundamental goals of the Building 2050 research program, the following hypothesis is proposed:

The main research assumption is that it is possible to achieve already in 2020 a building addressing the global climate issues of 2050 (I), according to high environmental performances (II), a high degree of usability (III), a remarkable architectural quality (IV), using the local economic potential (V).

- **(I) Addressing the global climate issues of 2050**

  We are currently able to define the CO_2 and energy savings that we have to reach in 2050 in order to set up some environmental objectives at the building component level.
  It is also possible to design a scientific concept that reaches these objectives.

  This covers especially the fundamental issues related to energy consumption and greenhouse gas emissions. Firstly, the predictable required performance to reach the 2050 issues will be defined. Then the Kaya equation applied to the built environment will help to identify the climate change major contributors. A scientific concept will be proposed in order to reduce these contributors according to the objectives.

- **(II) High environmental performances**

  It is possible to design a scientific concept that reaches the climate change objectives without any major cross-media pollution.

  This refers to the building's sustainability, through a more comprehensive approach than the one provided by the indicators already explored through the Kaya equation. This will make sure that the reduction of greenhouse gases and non-renewable energy will not increase other environmental impacts. Environmental specifications will be integrated in the smart living lab specifications.

- **(III) Usability level**

  It is possible to design a scientific concept that reaches the climate change objectives with a high usability level.
  It is also possible to predict the future user's behavior in order to design a flexible building.

  Functionality, modularity and building flexibility are important dimensions of a sustainable project. These issues will be developed based on the understanding of the future smart living lab user's lifestyle.

- **(IV) Architectural quality**

  It is possible to design a scientific concept that reaches the climate change objectives with a high architectural quality

  The expected scientific concept will have to contribute to the architectural quality of the smart living lab. This work will more focus on the design process that allows this architectural quality.
  That includes preliminary architectural studies, competition specifications, type of procedure, jury composition, jury decision-making process and the relative importance of the evaluation criteria.

- **(V) Local economic potential**
  The local economic potential with a new economic model contributes to the design of a scientific concept that reaches the climate change objectives.

  Technology transfer is part of the design process of the Smart Living Lab. In this sense, the proposed technical solutions should use the local potential and may be implemented thanks to a new economic model.

The synthesis of these five items of the Building 2050 research program will provide an answer to the main research question. Climate change, environmental and usability issues will be covered internally by the EPFL Fribourg. Issues related to architectural quality and the local economy will be joint work with partners.

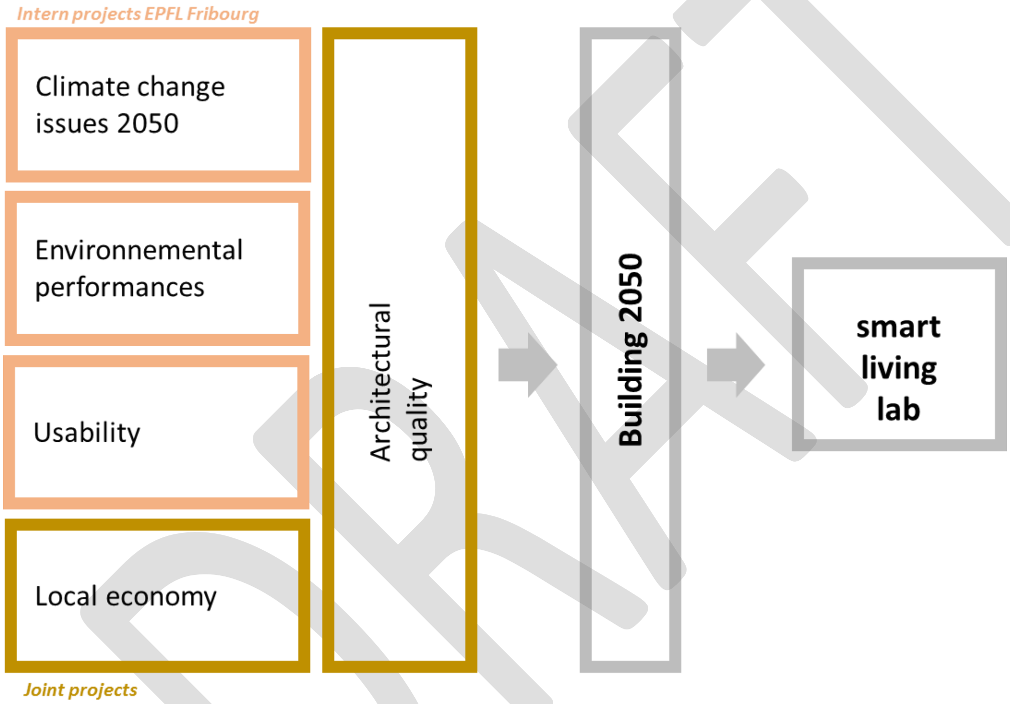


Figure 1 : The five items of the Building 2050 research program.

3 Scientific issues and research context

The objective of this chapter is to make understand the national and international issues the smart living lab will have to deal with as a building at the forefront of sustainable construction.

3.1 The global context

3.1.1 Kaya's equation

On a global level, the building sector in 2010 represented 32% of the final energy consumption and 19% of all the greenhouse gas emissions. These values could increase by two or even three times by the outlook to 2050, mainly because of population growth and built-up areas. On a global scale, in case of a frozen scenario or where the energy efficiency of a building cannot be highly improved, it can be seen on Figure 2 below, that the combination of the increasing number of households, coupled with the fact the number of persons per household keeps getting smaller, leads to a bigger built surface per person and consequently to a stronger energy consumption to the outlook 2050. Equally, the GDP exponential growth will make energy consumption of commercial buildings also double at the same time.

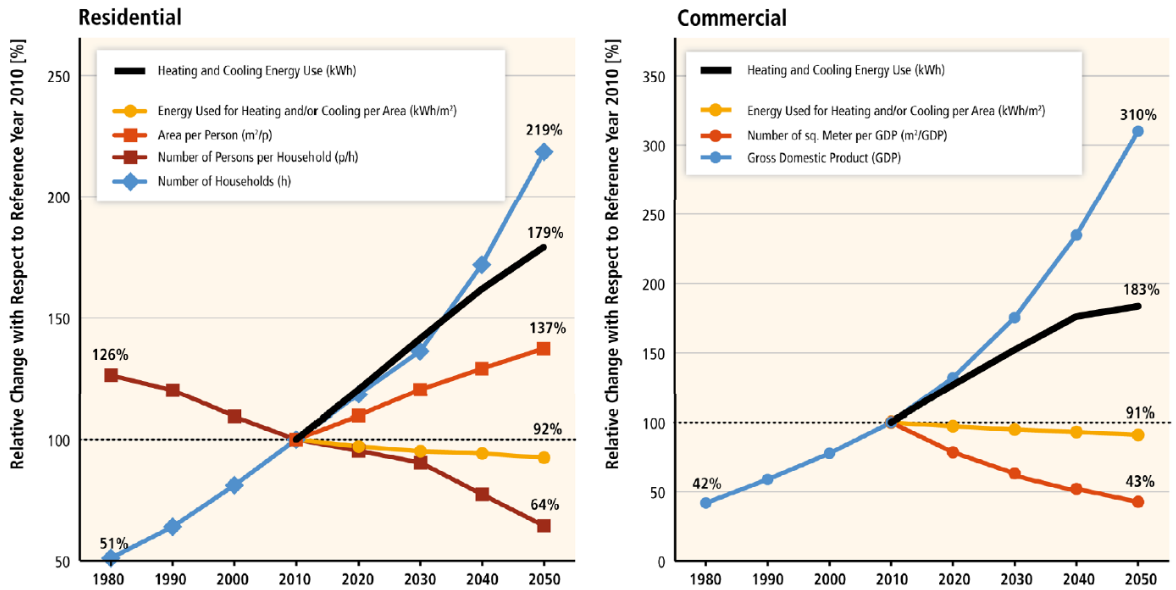


Figure 2 : Trends for the different variables on heating energy consumption and cooling of residential and commercial buildings (IPCC WGIII AR5, chapter 9, p17/103).

Moreover, in order to limit the global average temperature increase to 2°C, the greenhouse gas emissions will have to be reduced between 40%-70% - in relation to 2010 - by 2050 and almost entirely eliminated by the end of the century. Ambitious mitigation actions could demand a direct removal of carbon dioxide from the atmosphere[2].

The combination of these different factors shows that there is, on one side, a growing pressure from society due to its constantly increasing needs, and on the other side, the fact that we are supposed to meet the challenge to drastically reduce our greenhouse gas emissions.

[2] Source : IPCC

These different factors are well stated in the Kaya equation, developed by Yoichi Kaya[3], Japanese energy economist.

Considering the following variables:
CO_2: global CO_2 man-made emissions
POP: global population
GDP: global GDP
TOE: world consumption of primary energy (abbreviation of Ton Oil Equivalent)

We obtain the following equation[4]:

$$CO_2 = \frac{CO_2}{TOE} * \frac{TOE}{GDP} * \frac{GDP}{POP} * POP$$

$\frac{CO_2}{TOE}$: represents the carbon content of the energy used worldwide
$\frac{TOE}{GDP}$: represents the energy intensity of the economy
$\frac{GDP}{POP}$: represents the production per person

According to the conclusions of the IPCC above mentioned, in order to reduce by three our greenhouse gas emissions, the result of these variables will also have to be divided by three.

It can be observed that the following variables leave little room for progress:
- GDP per capita: international policies are based on an economic growth model or increase of 2% to 3%[5] a year (Figure 3), within a factor of 2 to the outlook to 2050, which is a reasonable objective.
- Global population: it should increase of 33% by 2050 to reach a median scenario of 9.6 billion compared to the present 7.2 billion (Figure 4).

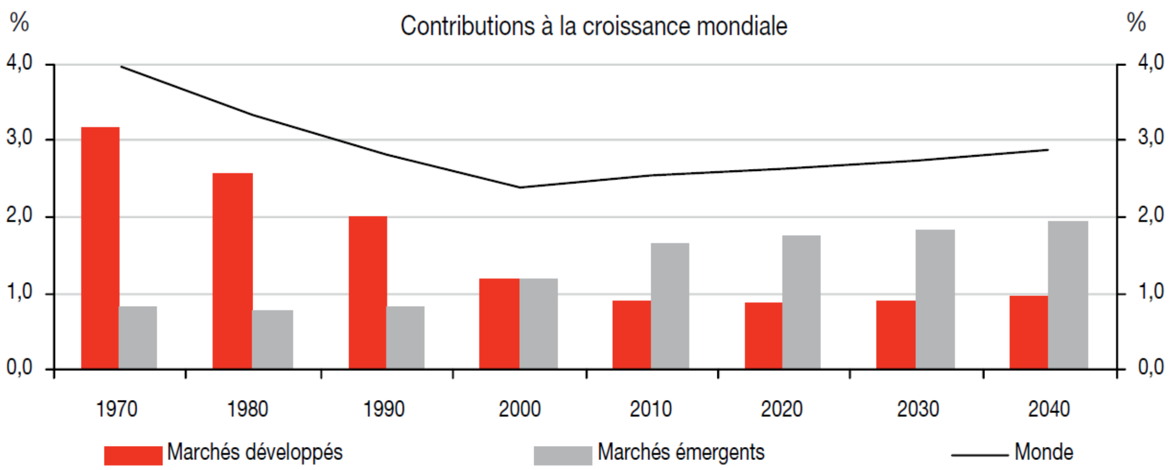


Figure 3 : Global growth of GDP (HSBC)

[3] Y. Kaya et K. Yokobori, *Environment, energy and economy: Strategies for sustainability* (Aspen Inst., Washington, DC (United States), 1998), http://inis.iaea.org/search/search.aspx?orig_q=RN:30022589.
[4] J-M Jancovici, Kaya's equation, www.manicore.com
[5] Karen Ward, « The World in 2050 - Quantifying the Shift in the Global Economy » (HSBC Bank plc, janvier 2011), \\antfrgenas1.epfl.ch\antfr-ge\4Building-2050\03.Ressources\vision 2050\hsbc-bwob-theworldin2050-fr.pdf.

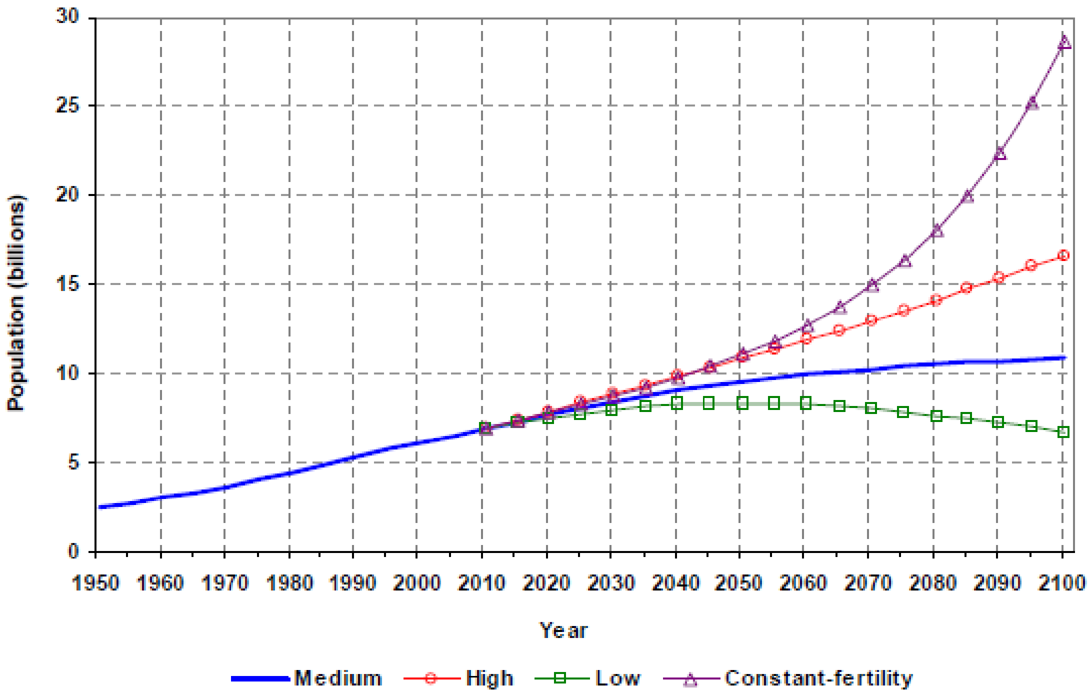


Figure 4 : Evolution of global population from 1950 to 2100 (UN secretariat – 2013)

Therefore, the only variables left that can be influenced are: the energy carbon and the energy intensity of the GDP. If the Kaya equation is rewritten with the values mentioned above, we can state that the result of these variables may be reduced by a factor from 9 to 12 (or each variable by approximately a 3 factor) to reach the goal to reduce the CO_2 emissions from the GIEC!

Moreover, a quick historic overview, shows in

that these two indicators haven't really changed in the past decades, and that they have even decreased during the last 10 years.

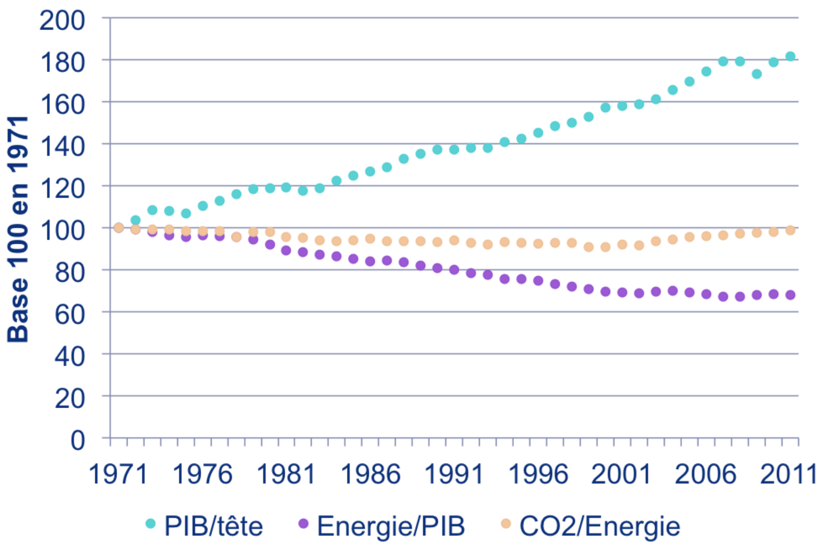


Figure 5 Evolution of Kaya equation parameters (carbone4 – Banque mondiale)

3.1.2 Building inertia

The very long life cycle of buildings, which leads to a low building stock renewal rate - around 1% a year in Europe - is one special feature of the construction industry.
There are three possibilities to tackle climate change and to allow buildings to constantly take advantage of the best possible available technologies:

- Limiting buildings' lifespan. This option does not seem sustainable, since it would miss a vital ingredient of building sustainability and would largely increase the impact linked to the embodied energy. This approach must nevertheless be verified
- Construct buildings whose conception allows flexibility and modularity
- Construct buildings today corresponding to tomorrow's standards

3.2 The Swiss context

3.2.1 The impact of climate change on Switzerland

The range of climate change in Switzerland depends on region and season, and particularly on the future evolution of global greenhouse gas emissions. The MeteoSwiss report uses two different non-intervention emission scenarios (A2 et A1B), predicting an increase on emissions, and one climate stabilization scenario (RCP3PD), which estimates that emissions will be reduced by around 50% by 2050. As an illustration, Figure 5 shows observed seasonal temperature and precipitation changes in Western Switzerland, as well as projected changes for the three different emission scenarios and selected time periods. [6]

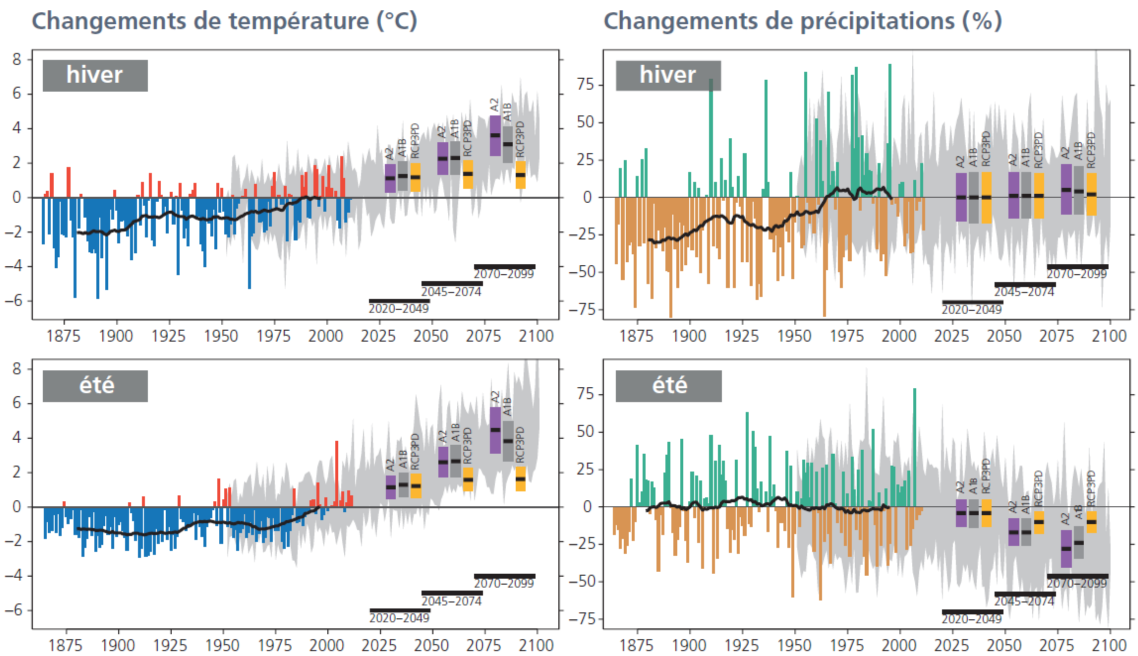


Figure 6 : Seasonal variation and climate evolution in Western Switzerland according to the different scenarios by the GIECC

In the best-case scenario, with a stabilization of climate change, the impact on thermal behavior of buildings will nevertheless be important with an increase of a minimal temperature of 1°C. By way of comparison, the variation

[6] Christof. Appenzeller et Center for Climate Systems Modeling., *Swiss Climate Change Scenarios CH2011* (Zürich: C2SM, 2011).

of one degree of the comfort setpoint temperature leads to an increase of around 10% to 20% of the energy demand to be able to meet this need. The impact of climate change on the smart living lab will therefore have to be considered.

3.2.2 A different context

In order to understand the Swiss context, it is worth characterizing the variables evolution of the Kaya equation on a national level.

Demographics

The fertility rate in Switzerland is one of the lowest worldwide, with an average of 1,5 children per woman for the past 40 years, compared to 2,5 children per woman on a global fertility rate.

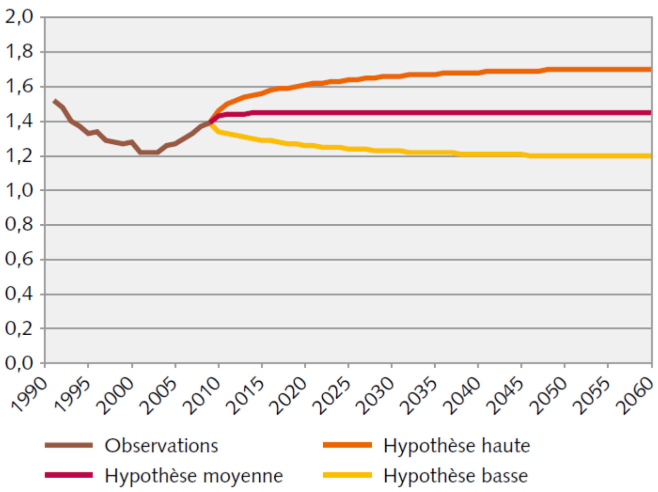


Figure 7 : Evolution scenarios on the average number of children per Swiss woman (OFS – 2010)

The demographics evolution to the outlook to 2050 is subject to public policies related to citizenship and immigration.

A study of the FSO in 2010 shows that for the « *next 50 years the Swiss population will increase of 840'000, from 6'111'000 to 6'950'000, while the natural balance accumulated during this period (-620'000) and the migratory balance (-374'000) are negative for the Swiss citizens. This increase is due to the number of new Swiss citizens (+1'833'000) compensating for these negative developments*. [7]»

It can be concluded that the Swiss population will increase of 840 000 inhabitants, that is to say a growth factor of 1.14 in the population by 2050.

It can also be observed on the following figure that the Swiss population will have by 2050 a more important proportion of elderly people with a much wider age structure from 60 years old.

[7] Raymond. Kohli, Schweiz., et Bundesamt für Statistik., *Les scénarios de l'évolution démographique de la Suisse 2010-2060* (Neuchâtel: Office fédéral de la statistique, 2010).

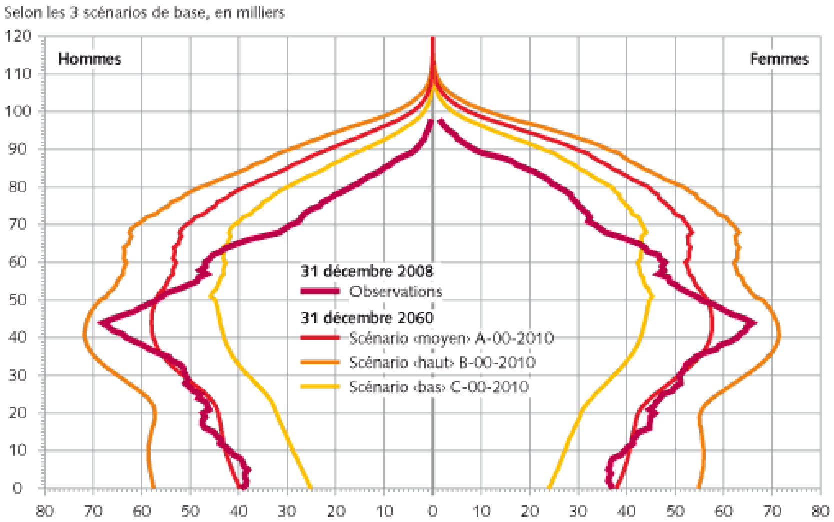


Figure 8 : Swiss population age structure (OFS – 2010)

GDP

In its report called « The world in 2050 »**Erreur ! Signet non défini.**, HSBC foresees an evolution of 215% of the GDP for Switzerland per person, which means a 2,15 factor, very close to the aforementioned global average. On the other hand, the SFOE[8] anticipates in its scenarios an increase of the GDP per capita of only 138% for the same period, as it can be seen on
Figure 9 :

Désignation	Source des données	Unité	2000	2010	2020	2035	2050
Population	OFS (2010)	Millions	7,2	7,9	8,4	8,9	9,0
PIB	SECO (2010)	Milliards CHF (réel, 2010)	464,2	546,6	617,9	700	800,7
Structures des bran-ches	Chancellerie fédérale et OFS, 2011, adaptation de Prognos		-	-	-	-	-
Surfaces de référence énergétique	Wüest & Partner adaptation de Prognos	Millions m^2	623,5	708,8	798,5	885,7	937,5
Volumes de trafic voyageurs (PPA et PCF)	ARE, 2012	Milliards personnes-km	100,1	114,2	131,1	146,0	151,3
Volumes de trafic voyageurs (NPE)	ARE, 2012	Milliards personnes-km	100,1	114,2	126,6	137,0	140,3
Volumes de trafic marchandises (PPA et PCF)	ARE, 2012	Milliards tonnes-km	23,6	26,9	34,2	40,3	42,3
Volumes de trafic marchandises (NPE)	ARE, 2012	Milliards tonnes-km	23,6	26,9	34,5	39,3	39,7
Prix: exemple du pétrole (prix du mar-ché mondial)	AIE, WEO 2010, «New Poli-cy», adaptation de Prognos	USD/baril (réel 2010)	34,3	76	99,9	114,1	116,9
	AIE, WEO 2010, «Scéna-rio 450», adaptation de Pro-gnos	USD/baril (réel 2010)	34,3	76	90,8	90,9	83,5

PPA: «Poursuite de la politique actuelle»
PCF: «Mesures politiques du Conseil fédéral»
NPE: «Nouvelle politique énergétique»

Source: Prognos 2012, OFS 2010, 2011, OFEN 2010, 2011, AIE 2010, ARE 2012

8 OFEN, « Perspectives énergétiques 2050 » (Office fédéral de l'énergie, s. d.), http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=fr&name=fr_75256679.pdf.

Figure 9 : Framework data on the energy outlook 2050, (SFOE – 2013)

Carbon and energy

Final energy consumption in Switzerland is represented in Figure 10 by the SFOE[9]. We can observe nature and history consumption. It kept growing since 1950 until its stabilization in the 2000s.

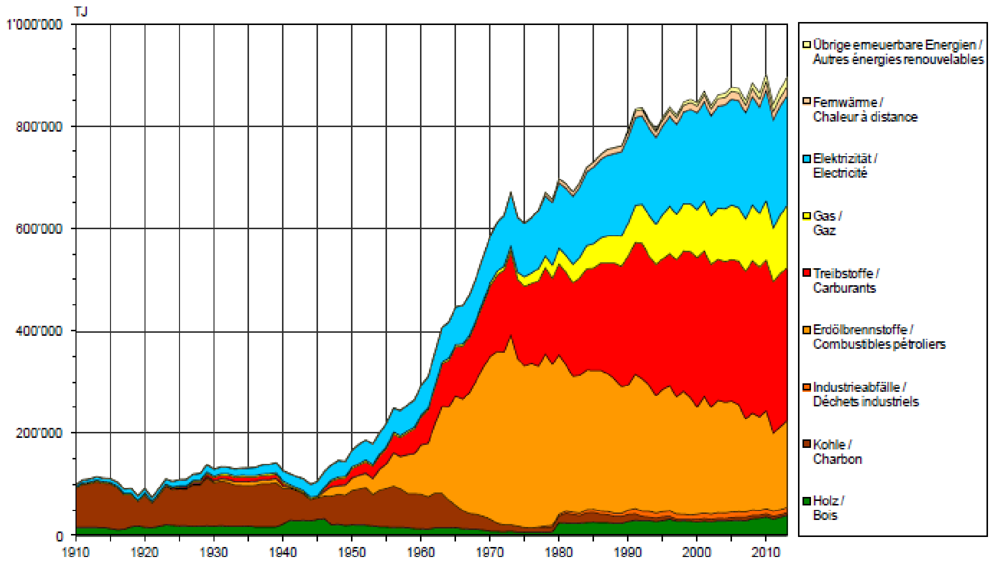
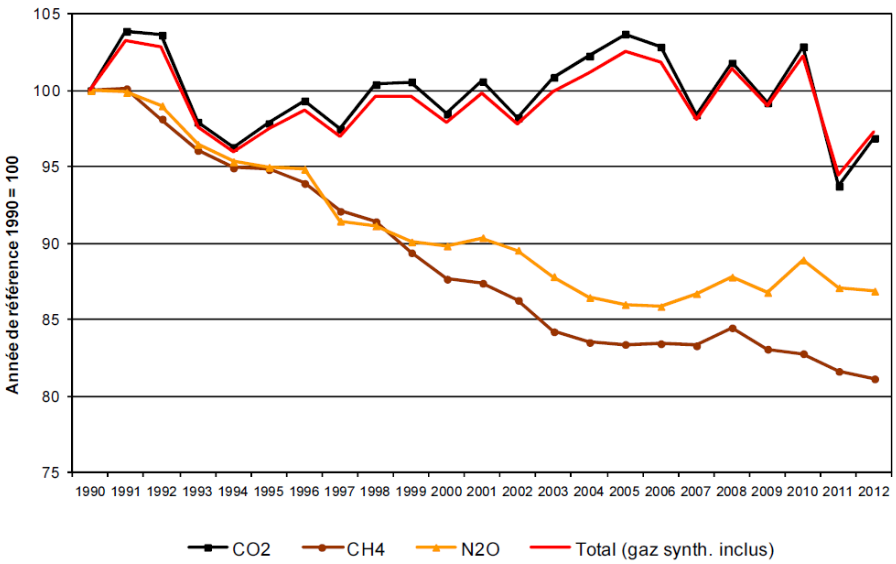


Figure 10 : Evolution the final energy consumption in Switzerland since 1910 (OFEN – 2013)

Regarding the greenhouse gas emissions, a recent study by the FOEN[10] has shown as in Figure 11 a significant decrease of gases CH_4 and NO_2 without however having a big impact on the total gas emissions. In fact, the important CO_2 share and its fluctuation is strongly linked to the use of heating and to the severe winter conditions.



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[9] OFEN, « Aperçu de la consommation d'énergie en suisse au cours de l'année 2013 » (Office fédéral de l'énergie, s. d.).
[10] Carla Gross - OFEN, « Indicateurs de l'évolution des émissions de gaz à effet de serre en Suisse 1990-2012 » (Office fédéral de l'environnement, s. d.).

Figure 11 : Evolution of carbon dioxide, methane and nitrous oxide emissions since 1990 (FOEN– 2014)

This report confirms that the issue of climate change on a national level must be analyzed through the whole life cycle of products consumed by households. Almost half of the greenhouse gas emissions linked to the consumption in Switzerland (53 million tons of carbon dioxide - CO_2 - equivalent to 48, 7 %) were thus emitted out of Switzerland in 2011 (Figure 12).

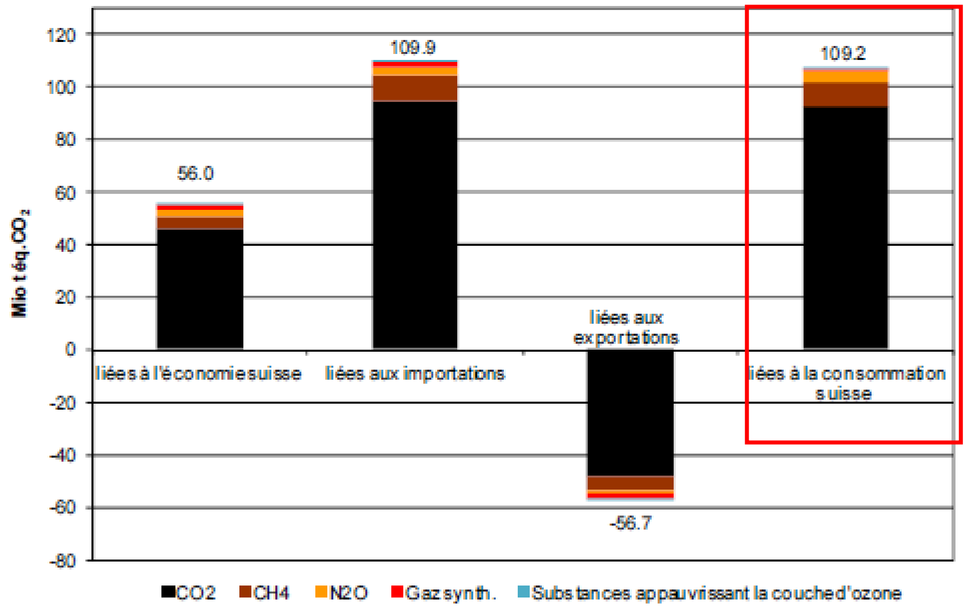

Figure 12 : Overview of greenhouse gas emissions of the Swiss economy in 2011 (FOEN – 2014)

Carbon dioxide's (CO_2) emissions in 2011 equalled 13,6 tons per capita, for a population of 7,954 million inhabitants. As shown in Figure 13, this phenomenon keeps progressing. It can be observed that although the greenhouse gas emissions in Switzerland have constantly decreased since 1996, the commercial gas emissions cancel out its benefit.

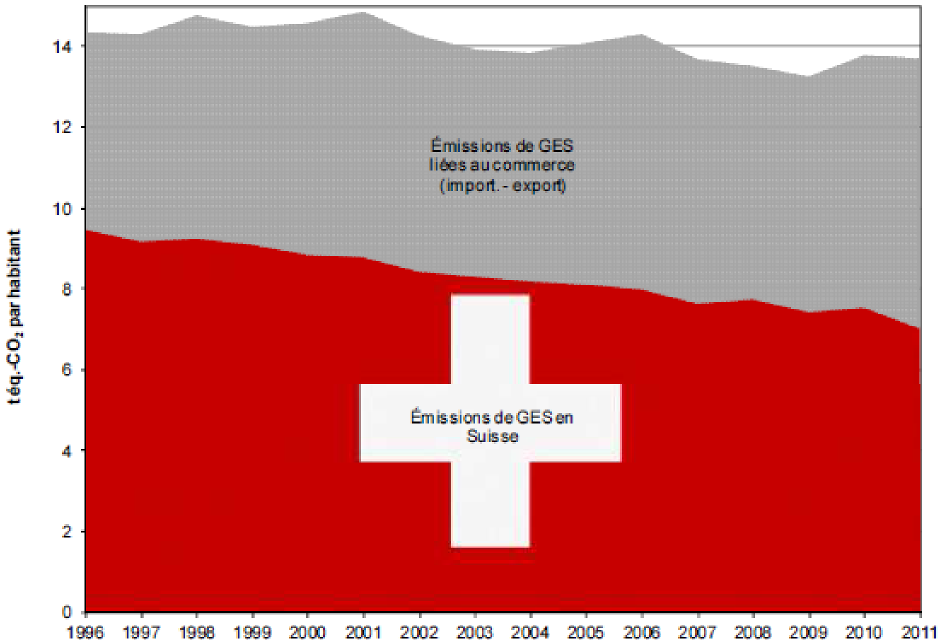

Figure 13 : Commercial greenhouse gas emission evolution in Switzerland (FOEN – 2014)

3.2.3 Similar objectives

Based on these assumptions, Kaya's equation can be updated for Switzerland to 2050 as follows:

CO_2 : CO_2 man-made emissions for Switzerland, factor 0,2 (-80%) outlook 2050
Pop : Swiss population, factor 1,14
$\frac{GDP}{Pop}$: GDP per-capita between 1,38 and 2,15 depending on the source

If these factors are integrated into the equation:

$$CO_2 = \frac{CO_2}{TOE} \times \frac{TOE}{GDP} \times \frac{GDP}{Pop} \times Pop$$

We can reach the conclusion that in order to stick to a decrease of the greenhouse gas emissions by 80% in Switzerland, each of the following factors $\frac{CO_2}{Toe}$ and $\frac{Toe}{GDP}$ has therefore to be divided by 2,8 to 3.5 according to the GDP value source.

In spite of the significant differences between GDP and population, and because of the ambitious goal to reduce CO_2 emissions by 80%, the effort to produce on the GDP Swiss energy intensity and on the energy carbon content is the same as on a global level, namely, the result of dividing roughly by three every one of these indicators.

3.2.4 The energy strategy 2050

On May 25th 2011, and after the Fukushima disaster, The Federal Council decided to phase-out nuclear power by 2034.

In order to tackle that, the confederation has implemented a new strategy outlook to 2050 with the *New energy policy* and the energy act adopted by the federal council on September 4th, 2013. This policy sets new objectives: « *… energy-related CO_2 emissions in Switzerland, will range between 1 to 1.5 ton per inhabitant in 2050. In order for this goal to be reached, the energy-related CO_2 emissions - which were of around 40 million tons in 2010 -*

should be reduced of 7.6 million tons by 2020. The reduction of CO_2 emissions should reach 14.3 million tons by 2035 and around 31.9 million tons by outlook 2050.[11] »

An initial package of specific measures was adopted by the Federal Council on April 18th, 2012. Therefore, as of 2020, « *new buildings will supply their own energy as independently as possible all throughout the year and will generate an appropriate share of the electricity they consume*[12] »

3.2.5 The 2000W society

According to the SIA[13], in order to stop the climate change, we should limit the energy consumption to 2000W per inhabitant, of which only 500W should come from fossil fuels by 2150, that is to say a volume of CO_2 emissions of one ton per inhabitant per year.
The medium-term objective should be to reach 2000W fossil fuel in 2050; i.e., around 2 tons of CO_2 per inhabitant per year (Figure 14).

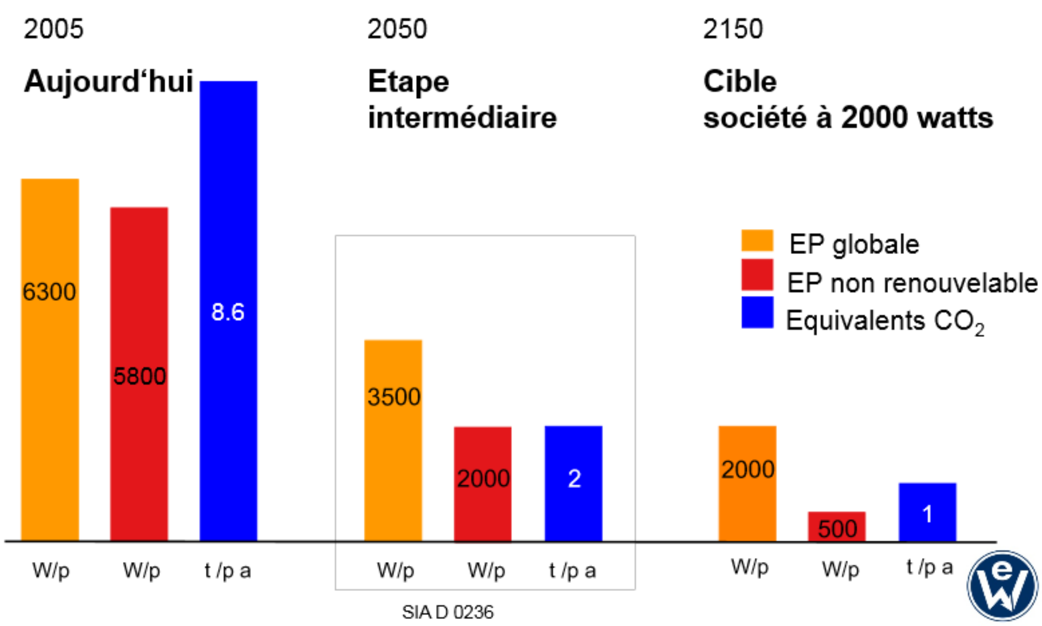

Figure 14 : The goal of the 2000 Watts society (Weinmann-Energies SA – 2012)

This double approach, energy and CO_2 is based on a double issue: 2000W per inhabitant would be the bare minimum needed for the development of a society as shown in Figure 15 :

[11] Conseil Fédéral, « Rapport explicatif concernant la Stratégie énergétique 2050 », 28 septembre 2012.
[12] OFEN, « Stratégie énergétique 2050: premier paquet de mesures » (Office fédéral de l'énergie, 13 septembre 2012).
[13] Hans-Ruedi. Preisig, Katrin. Pfäffli, et Société suisse des ingénieurs et des architectes., *Objectifs de performance énergétique SIA : D 0216* (Zurich: SIA Société suisse des ingénieurs et des architectes, 2008).

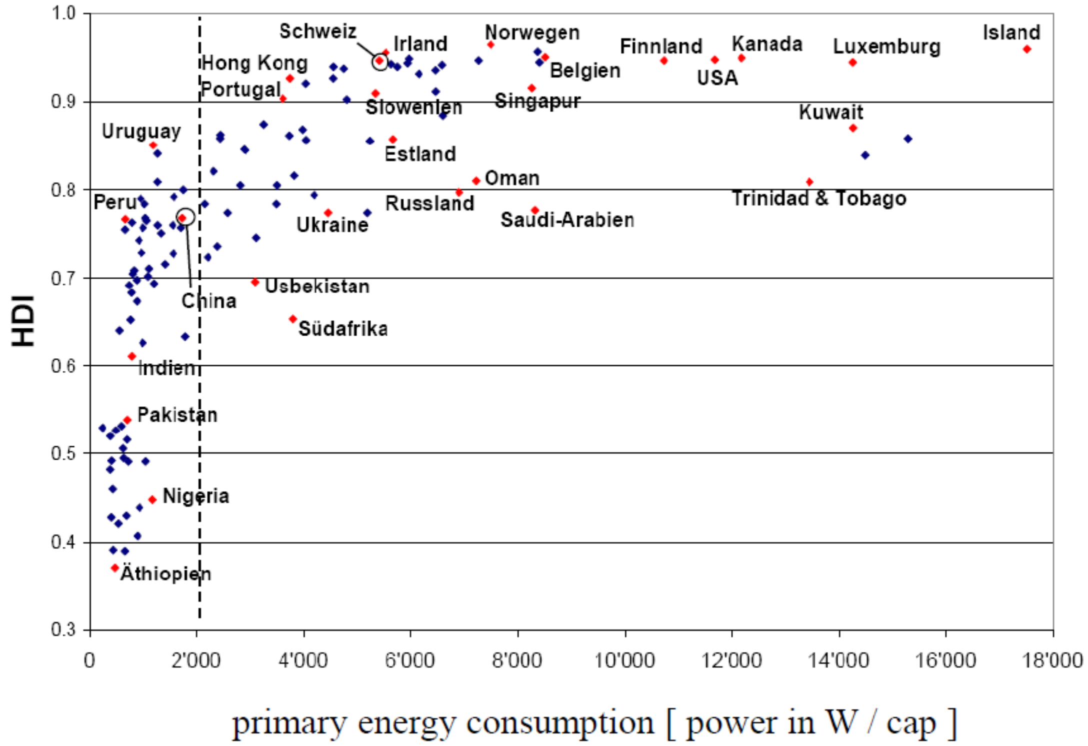

Figure 15 : Evolution of primary energy consumption in relation to the human development index (UNDP - 2006)

However, this power limit is not necessarily correlated with a decrease of the greenhouse gas emissions (GHG). So, these 500W of fossil fuels have been set as a second objective corresponding to 1 ton of CO2-eq, which is the acceptable limit defined by ETH and based on IPCC studies provided the global population does not exceed 10 billons in 2150.
Moreover, this double objective will also try to limit the Khazzoom–Brookes postulate effect, that argue that increased energy efficiency paradoxically tends to lead to increased energy consumption[14].

Regarding these two objectives, it's the latter that seems the most difficult to achieve, according to Notter, Meyer and Althaus[15]. In their study, different analysis have been carried out to characterize the environmental and energetic pressure of a sample of 3369 Swiss inhabitants in a « bottom-up » approach, when these rates are commonly evaluated with a « top-down » methodology.
It can be observed (Figure 16) that 10% of the inhabitants in this sample are already living within the 2000W, with maximum values of 20 000-Watts. In contrast, no one goes beyond 1 t éq-CO_2.

[14] L. Schipper et M. Grubb, « On the Rebound? Feedback between Energy Intensities and Energy Uses in IEA Countries », *Energy Policy* 28, nº 6- 7 (2000): 367- 88, doi:10.1016/S0301-4215(00)00018-5.
[15] D.A. Notter, R. Meyer, et H.-J. Althaus, « The Western Lifestyle and Its Long Way to Sustainability », *Environmental Science and Technology* 47, nº 9 (2013): 4014‑21, doi:10.1021/es3037548.

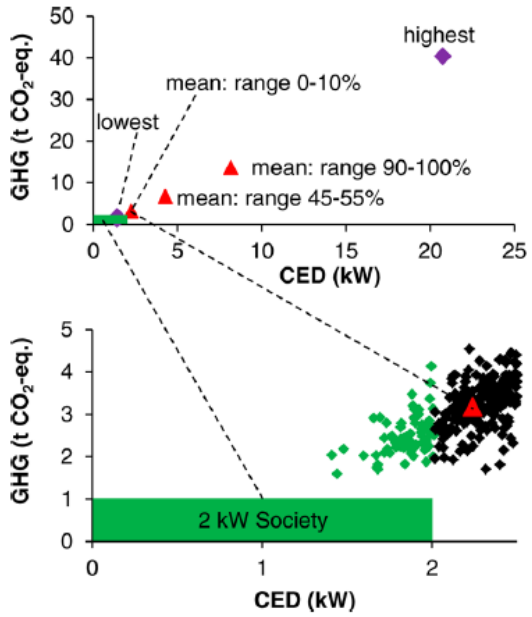

Figure 16 : Cumulative energy demand of a selected sample of Swiss households according to their CO_2 emissions (Notter – 2013)

In order to better understand which way of life a Swiss citizen should adopt to limit his energy consupmtion to 2000W, the study shows in Figure 17 the consumption of goods and services not to be exceeded. In terms of mobility, 1690 km a year by car and a flight every 6 years can be quite striking and provide some orders of magnitude. We can therefore conclude that, in order to establish a sustainable society and in spite of the significant increase in technology efficiency, changing our way of life will be necessary.

			CED		GHG		EI99	
	mean	%	kW	%	tCO_2-eq	%	points	%
meals/week with meat (number)	2.79	85.3	0.246	96.1	0.904	91.3	111	90.3
driving the car (km/year)	1690	17.6	0.235	17.1	0.444	17.2	30.7	17.1
flights/year (number)	0.178	19.2	0.020	8.32	0.042	8.36	2.88	8.36
public transportation (minutes/week)	172	47.1	0.083	52.3	0.039	61.7	3.84	57.3
household electricity (kWh/year)	6000	94.4	0.685	94.4	0.074	94.4	18.4	94.4
heat energy (kWh/year)	2880	41.6	0.430	39.3	0.743	42.1	46.1	42.0
heated area (m^2)	34.7	57.5						
heat energy demand per m^2 (kWh/(m^2*year))	83	69.7						

Figure 17 : Key parameters for a 2000W-Society compatible lifestyle. Environmental impacts represented in cumulative energy demand (CED), greenhouse gas emissions (GHG) and eco-indicators (EI99) (Notter - 2013)

4 Research boundaries

The analysis will not be limited to the environmental impact of the building's activity. The scope of the life-cycle assessment will be broadened to an urban scale to better assess the building and its induced impacts resulting from food and mobility.

4.1 Life-cycle assessment

These analysis will be carried out according to ISO 14040 serie of standards, which defines every step of the LCA. The objectives of this analysis will be to verify the compliance of the scientific program with the sustainable criteria to 2050.
In order to focus on climate change issues, the analysis will mainly use indicators from energy resources consumption and climate change.
To avoid pollution transfers, other indicators will be evaluated through an analysis of the global project life cycle. According to the work being carried out at the Scientific and Technical Centre for Building (CSTB) in France, these indicators could be limited to 4 for visibility's sake, assuring the comprehensiveness of the impacts: climate change, ecotoxicity, ionizing radiation and land use.

The functionality of the building will consist in offering around 15 housings and hosting the research activities applied to a group of 80 researchers in a 50 -100-year period. The target users are to be defined.
The impact will be rated per person and per year, in order to put results into perspective with international objectives and in relation to the real smart living lab population.

4.2 Building scale

Constructing a building today to meet the environmental expectations of 2050, means it should be 35 years ahead of its time. What will remain of the building in 35 years' time? The question is worth asking. On one hand, we must anticipate the lifespan of its components and find a way to allow their easy renovation, if needed, before 2050. On the other hand, the components which will not be renovated over this period of time, will have to be designed in such a way as not to limit the evolution of the other components.

The department of real estate and buildings of canton Bern defines three different systems to help classify the components of a building[16] :

- The primary system: long lifespan, from 50 to 100 years. This includes the site preparation, the supporting structure, and the roofing. These are mostly invariable components.
- The secondary system: average lifespan, from 15 to 50 years. It includes the inner walls, the floors and ceilings, fixed installations and networks. These are adjustable components.
- The tertiary system: short lifespan, from 5 to 15 years. It includes household appliances, design and furnishings. These are changeable components.

Within the scope of our study, and given the long-term perspective of the project, the research will be based on the primary and secondary systems. As an example, the terminals for home automation and smart energy management will not hold a central place in the research program, although they will be delivered with the smart living lab building. The issue will focus on the capacity of the primary and secondary systems to accept the installation and replacement of the tertiary components.

4.3 Urban scale

The construction of the smart living lab building will have an impact on an urban scale, mainly in terms of mobility and food. Beyond the building, the environmental impact of the users will also be conditioned by the building's position, determining the commuting and eating habits during the working time. As shown in the Notter, Meyer

[16] OPB, « System Separation » (Office for Properties and Buildings of the Canton of Berne, 2006).

and Althaus studyErreur ! Signet non défini. based on a sample of Swiss households (Figure 18), the cumulative building-related impact linked to food and mobility, represents 80 to 90% of the carbon and energy impact per inhabitant.

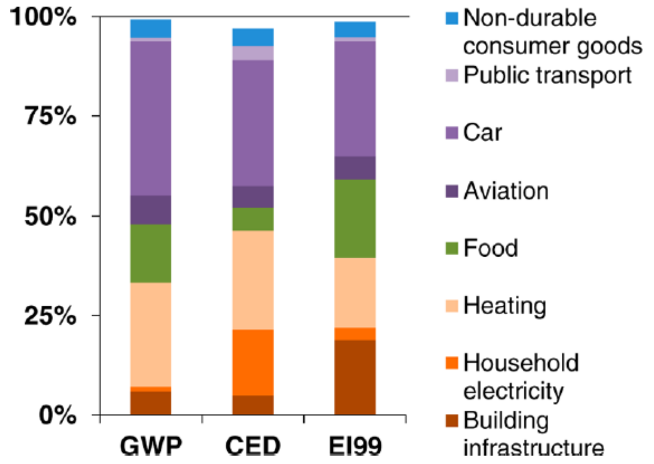

Figure 18 : Distribution of environmental impacts according to household use in Switzerland (Global Warming Potential, Cumulative Energy Demand, EcoIndicators99) (Notter – 2013)

It is therefore essential to evaluate these impacts, in order to propose ways to improve the on-going urban development on the BlueFACTORY site or even to propose solutions at the urban scale that could influence sustainable eating habits and mobility.

5 Methodology

5.1 Grading

The research program has to clearly point out the major improvement directions to be developed in order to construct a building that best suits the 2050 performance objectives.
Thus, we will have to define what should be the smart living lab footprint according to the current best practices and according to the 2050 objectives. The negative product between these 2 footprints represents the improvement this program should offer by proposing suitable technical and architectural solutions. We will call it the scope of efficiency improvement.

Figure 19 : scope of efficiency improvement for the Building 2050 research program

5.2 Splitting the project

In order to model the scope of efficiency, the smart living lab has to be split into performance indicators that will make up some design driving forces for the building sustainability. Dedicated experts will take care of these driving forces and will be in charge of the performance of these indicators. It would now be interesting to rewrite Kaya's equation and apply it to the smart living lab.
This equation do not pretend to be exhaustive as it doesn't take into account the qualitative aspects, but it clearly points out the major performance contributors.

CO_2: smart living lab CO_2 emissions. This is the target that we have to specify and that we want to reach.
POP: smart living lab inhabitants.
OEn: operating energy needs for the use of the smart living lab
EE: embodied energy consumption for the smart living lab construction
Bvol: built volume of the smart living lab

The following equation is obtained:

$$CO_2 = \frac{CO_2}{OEn} \times \frac{OEn}{EE} \times \frac{EE}{Bvol} \times \frac{Bvol}{POP} \times POP$$

The CO_2 objectives have to be defined for each different usages of the smart living lab (offices, housing…). Then, the population that will be taken into account will be also different regarding to the usage.

$\frac{CO_2}{OEn}$ Equals carbon intensity of operating energy needs. Systems with a high energy conversion efficiency and a low-carbon source should be used to address the smart living lab requirements. The research field linked to the **active energy systems** will address this indicator.

$\frac{OEn}{EE}$ Equals energy intensity of the building use regarding to the implemented embodied energy. Energy-efficient, easy-to-implement materials will have to be used to best limit the building's energy consumption. The research field linked to the **passive energy systems** will address this indicator.

$\frac{EE}{Bvol}$ Equals the energy intensity linked to the building implementation in view of the built volume. The built volume will have to be created to best limit the smart living lab embodied energy consumption. The research field linked to the **life-cycle analysis** will address this indicator.

$\frac{Bvol}{POP}$ Equals the built volume in view of the smart living lab inhabitants. The building has to be optimized to meet the user's needs. The research field linked to the **flexibility and modularity** will address this indicator.

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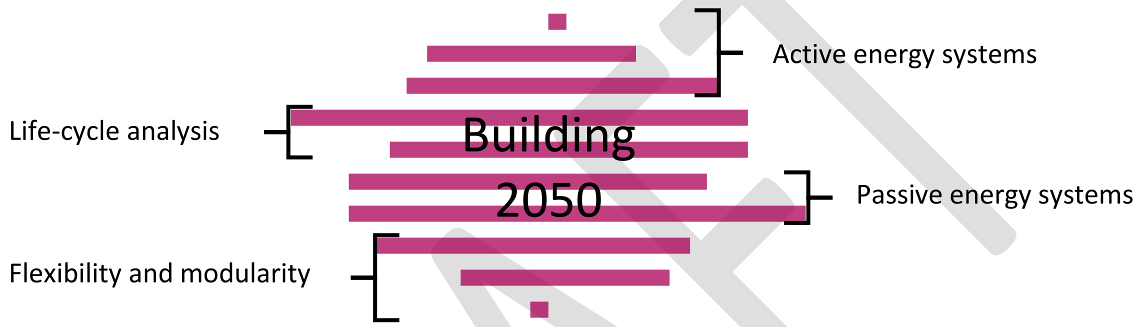

Figure 20 : splitting the scope of efficiency improvement

These research fields allows the project splitting in order to define roles and responsibilities. Kaya's equation shows, however, the interdependence of each one of these fields, since the global performance depends on a set of indicators, and that each research field depends from another one.

5.3 State of the art and scope of efficiency: definitions

The objective of this stage previous to the development of a scientific concept to build the smart living lab, is, on one hand, to identify the performance indicators inherent to each one of the 4 identified fields of research, and on the other hand, to carry out a state of the art in constructive and architectural techniques allowing to meet the smart living lab's specific requirements.

5.3.1 State of the art on the built environment

Each research field will match the following elements:

- Which are the cutting-edge research labs in each field?
- Which are the most performant buildings bearing similarities with the smart living lab program constructed to date?
- Which is their impact and energy consumption?

5.3.2 Identifying the scope of efficiency

This scope will be built in two phases and will be carried out within the research field LCA described in paragraph **Erreur ! Source du renvoi introuvable.**.

Modelling of the environmental impacts of the smart living lab based on the state of the art

Based on the state of the art, which will allow to know the best available current practices, the use of a digital mock-up will allow us to estimate the project's environmental impact, as it would have been currently developed. We will use the feedback based on the experience and monitoring of similar buildings.

Modelling of the smart living lab's environmental impacts to meet the outlook to 2050 requirements

Based on the predefined global environmental performance objectives for 2050, the smart living lab's share will have to be identified, and its objectives split in order to set the target values for all components of the future building, similarly to the work carried out by the SIA[17] as shown in Figure 21.

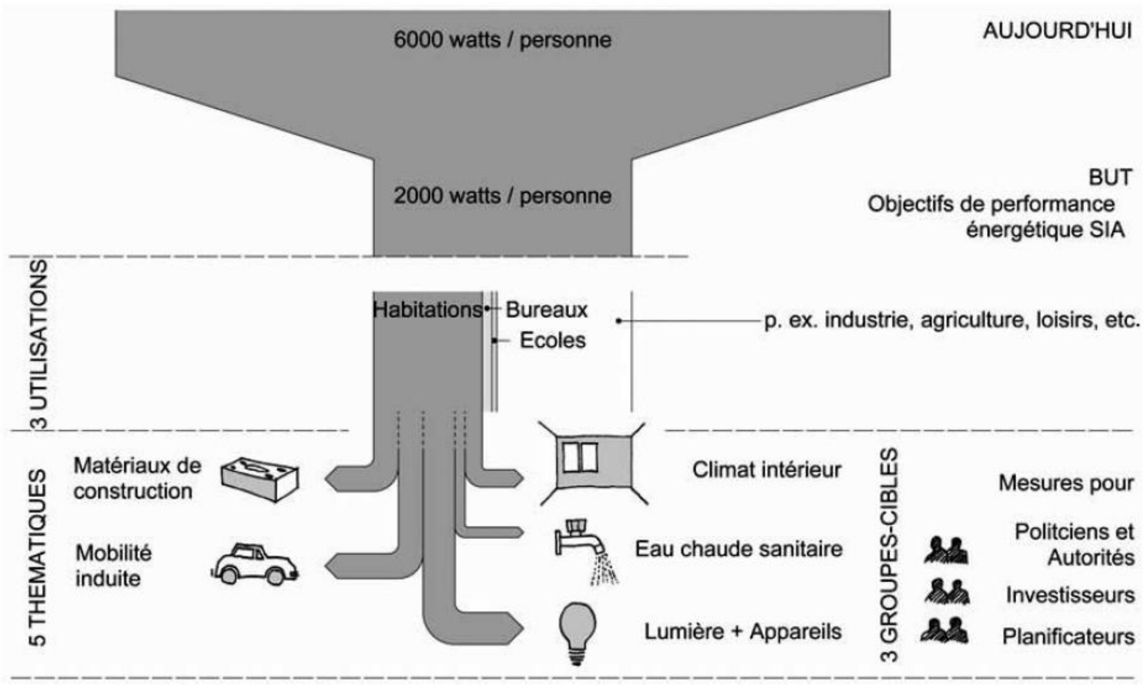

Figure 21 : 2000-Watt society goals with regard to the city's residential, school, and office buildings (SIA – 2008)

At the end of these two modellings, the scope of efficiency will be identified, pointing out the field studies or difference between the current practices and the most important objectives.

5.3.3 Carrying out a state of the art on a technical and constructive level

Highlighting the most important research fields will allow us to carry out a state of the art focusing on a technical and constructive scale in order to create solutions capable of providing enough efficiency to meet the 2050 performance objectives.

5.4 Representing the project

For the development of the future research phases, it will be necessary to design a first architectural volume that will be used for environmental and numerical simulations.

An architect will be recruited to carry out feasibility study of the project, which will contribute to propose volumes matching the preprogram and the urban regulations. These volumes will then be modelled and will undergo parametric variations to supply these 4 research fields.

5.5 Research / digital mock-ups

After this initial phase, the aim of this work is to offer a scientific concept that will include the detailed proposal of technical and constructive solutions, as well as the evaluation of their efficiency. In order to do that, a global

[17] Preisig, Pfäffli, et Société suisse des ingénieurs et des architectes, *Objectifs de performance énergétique SIA*.

strategy will be implemented. The state of the art will have allowed to further develop the discussion on the issue at the building and technical scale.

This strategy will also allow to set the technical and architectural options, namely the following bioclimatic parameters:

- Inertia
- Solar potential
- Insulation
- Transparence

And technical strategies:

- Centralization/decentralisation
- High/low temperature
- Production/distribution/diffusion
- …

A development work of this strategy will be carried out in every research filed.

5.5.1 Flexibility / modularity

As a reminder, this research field is characterized by the indicator $\frac{Vbat}{Pop}$ representing the built volume in relation to the smart living lab inhabitants. The built volume will have therefore to be limited, according to the needs of the future building users.
The needs of the future users will have to be identified by means of a sociological study, which will allow to improve the usability of the building. This usability will have to be considered on the long term, which means its modularity and flexibility will have to be studied.

Usability
The first step will consist in determining the needs of future users.
A behavioral study of a similar population represented on the three partner campuses of the smart living lab (UniFr, EIA, EPFL) will allow to characterize the smart living lab inhabitants from a qualitative and quantitative point of view, on the studied fields: activity within the building, mobility and food.
This analysis will be carried out with the help of Pr. Vincent Kaufmann, from the EPFL's Laboratory of Urban Sociology.

The study will involve three stages:

- Carrying out of the survey instrument and targeting of the future population
- Use of the instrument such as interviews and online large-scale surveys
- Analysis and use of test results

Based on this, the challenge will be to improve the usability notion of the smart living lab, according to the ISO 9241-11, which proposes the following definitions:

Usability: *is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use.*
Effectiveness: *accuracy and completeness with which users achieve specified goals.*
Efficiency: *resources expended in relation to the accuracy and completeness with which users achieve goals.*
Satisfaction: *freedom from discomfort, and positive attitudes towards the use of the product.*
Context of use: *users, tasks, equipment (hardware, software and materials), and physical and social environments in which a product is used.*
Work system: *system, consisting of users, equipment, tasks and a physical and social environment, for the purpose of achieving particular goals.*

This work will build on work already done on this field[18,19] and it will allow to qualify the functionality of the smart living lab building as a "tool-building".

The issues of this work can be summarized as follows:

- Maximizing the number of occupants for the built volume without harming the usability of the building, i.e., by means of the multipurpose of spaces.
- Increasing the effectiveness of the smart living lab by proposing environments suitable for work, that provide the greatest added value
- Proposing a comfortable work environment, equipped to limit the user's mobility
- …

Flexibility

The first part will have made possible to propose a reduced built volume keeping a high level of usability upon building delivery. A building may all throughout its life-cycle, due to the constant societal and demographic evolution, be reassigned to fulfill a different function from the one it was originally built for.
Since the environmental performance of the building is expressed in time units, it is easy to understand the potential effectiveness of making its life-cycle last longer.
This usability will therefore have to be maintained, limiting human intervention in the smart living lab. This is the flexibility notion, that's to say, the capacity of the built environment to adapt itself to a different or progressive use.
In order to achieve this, an operating range with up and down scenarios will be established, thus setting the flexibility objectives of the overall smart living lab spaces. The transformation of office spaces into experimenting labs or vice-versa could be envisaged, for instance.
This flexibility will also allow the project to adapt itself to new needs during the development phase or during the construction work.
This concept of flexibility will be implemented thanks to a systemic approach of the classification of the building's components, in relation to their life-cycle and their foreseeable obsolescence, to ensure the continuity of work in the Canton of Bern[Erreur ! Signet non défini.]. The renewal of the future building's components will be possible and easy, generated by a behavioral change or the end-of-life of its components.

Modularity

The concept of modularity in a building means the capacity to adapt the built volume to a particular use. The flexibility expresses itself within a specific volume.
The concept of module is linked to the industrialization of the construction process, which allows a prefabrication and offers many advantages:

- Reduced construction work to limit nuisance on the construction site
- Prefabrication, providing better work conditions and better performance
- More developed upgradability thanks to the assembling. This would make reversibility more conceivable.

From a sustainable point of view, the industrialization will be studied locally in order to enhance the socio-economic fabric close to the smart living lab.
It will have to be considered whether it's possible studying a different economic model. As a matter of act, the modular construction at present follows this criteria:

- Investment in a cumbersome and costly production system
- Rationalization of the construction process with constraint dimensions by transportation
- National or international transportation of the prefabricated elements to the construction site

[18] Keith. Alexander, *Usability of Workplaces Phase 2* (Rotterdam: International Council for Research and Innovation in Building and Construction, CIB General Secretariat, 2008).
[19] Gabriella Duca, « Usability Requirements for Buildings: A Case Study on Primary Schools », *Work (Reading, Mass.)* 41 Suppl 1 (2012): 1441‑48, doi:10.3233/WOR-2012-0335-1441.

- Assembly of the frame structure on site and finishing work

Under these conditions, the advantages of modular construction are well exploited from a technical point of view, but the benefit in terms of sustainable development is limited by the transportation impact and the absence of enhancement of the socio-economic fabric.

Another model that could be studied is as follows:

- Investment in a light and movable production system
- Temporary installation of industrial halls undergoing restructuring next to construction site
- Development of a construction process adapted to local resources (materials and workforce)
- Complete prefabrication onsite, including finishings with local companies

The benefits of this model will be studied within the scope of this research field.

5.5.2 LCA

As a reminder, this research field is characterized by the indicator $\frac{EE}{Vbat}$ which represents the energetic intensity linked to the building life-cycle in relation to the built volume. The construction volume will therefore have to limit the embodied energy consumption of the smart living lab.
The built volume is considered as impact generator on an urban scale in relation to mobility and food.
The overall functional requirements will be characterized by the sociological study of the behavior of future users. Environmental impacts caused by these needs will be accounted and compared to the 2050 objectives in order to identify the efficiency scope described in paragraph 5.1**Erreur ! Source du renvoi introuvable.**.
Performances will be evaluated in relation to two indicators: CO_2 emissions and energy consumption. However, other indicators will be used to ensure comprehensiveness of the impacts: climate change, ecotoxicity, ionizing radiation and land use.

Splitting the objectives

Energy and CO_2 quotas could be allocated to the smart living lab requirements in order to match the requirements of the project. Thanks to the splitting of the building, these quotas will allow to aim at a performance level for each one of its components. The sum of quotas will equal the target value compatible with the 2050 objectives, such as, for instance, the 180 kWh_{ep}/m^2/year proposed by the la SIA[20] for construction, exploitation and mobility, without forgetting to add food. The proportion between the different quotas will be identical to the one found on present projects, assuming the energy efficiency can progress identically for all of the building's components.
The performance level and the boundaries that define the 2050 objectives are not yet really clear and their definition will be part of this research.

Table 1 illustrates the approach. The research field linked to the flexibility will define the needs of future smart living lab users. The research field LCA will define the current consumption of all these needs based on the state of the art and the consumption objectives compatible with 2050.

[20] « SIA 2040 / 2011 La voie SIA vers l'efficacité énergétique » (SIA Société suisse des ingénieurs et des architectes, 2011).

Flexibility field	LCA field	
Needs	2015 consumptions	2050 objectives
Writing	100	33
Meeting	25	8
Lighting	70	23
Climate control	50	17
Washing	120	40
Mobility	30	10
Storage	70	23
…	…	…
Total	540	180

Table 1 : Goal-setting example

The smart living lab 2050 objectives will be split according to the different functionalities that it houses: housing, offices, experimental areas.

Secure and control performance

With the support of other three research fields, the proposed scientific concepts will have to be verified, to see whether they comply with a global, multi-criteria approach in order to avoid pollution transfer.
Thus, the global survey of the research program objectives is under the responsibility of this holistic research field.
In order to guide the program on the whole smart living lab lifecycle stages (design, construction, and use), sensibility analysis will be done allowing to highlight the most sensitive parameters on the environmental performance.
According to the Pareto principle, roughly 80% of the effects come from 20% of the causes (Figure 228).

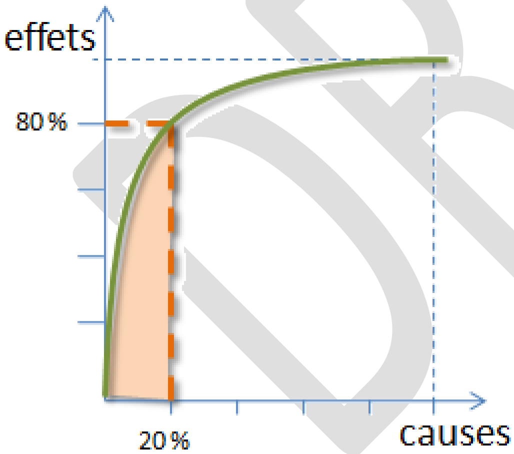

Figure 22 : Pareto's principle

In view of the numerous parameters involved within a building project on an urban scale, the Pareto's principle will allow to handle most of the effect with minimal parameters.
These parameters will be highlighted in the operational program, for a better understanding by the future designers. During construction work, a special attention will be paid to these parameters, thanks to specific checks and controls. A performance obligation could be asked to companies regarding to these highlight parameters.

Creating a performance tool for the smart living lab

The LCA field will also take care of the production of an integration tool for the overall results of the 4 research fields. The purposes of this tool will be:

- Splitting/segmenting the objectives as described above, in order to verify the energy and CO_2 quotas allocation to reach the global performance compatible with the 2050 issues.
- Tracking in real time the performance of the proposed scientific concept, replacing the objectives by the proposed real performance as the research program moves forward
- Constructing a simplified version of the tool, will allow – in future consultation procedure with companies - to self-assess the proposed projects and a monitoring framework of the different projects for the contracting owner

The three other research fields will participate to the construction of this tool.

Mobility and food

The impact caused by the smart living lab on an urban scale will be analyzed by this research field, which will also propose mobility and food solutions.

5.5.3 Passive systems

As a reminder, this research field is characterized by the indicator $\frac{OEn}{EE}$ which represents the energy intensity linked to the building's requirements in view of the consumed embodied energy. More embodied energy-efficient materials will have to be used for the building envelope, whose implementation allows to best limit the operating energy needs linked to the desired comfort.

The target energy need together with the carbon content and the materials-related energy, will be fixed by the allocated quotas within the LCA research field.

Given that the building's envelope is the first filter which separates internal and external climates, it is worth to first characterize these two climates. Based on this analysis, a bioclimatic strategy will be developed and evaluated by parametric and dynamic thermal simulations allowing to emphasize the most influential physical parameters having an effect on comfort and operating energy needs within the smart living lab. The effectiveness of the proposed bioclimatic strategies will be put into perspective in a life-cycle approach to verify that the energy reduction need is not cancelled out by the building's embodied energy need.

Characterizing the impact of the smart living lab occupants on the internal climate

The needs and activities in the sociological study described in paragraph 5.5.1, will be converted into energy needs and therefore in potential internal heat gains.

An hourly use of this internal heat gain will be established by programmatic areas with identical thermic behavior.

Characterizing the Fribourg climate

Weather data will be chosen according to the method defined. It'll have to be representative of the Fribourg climate and will allow to calculate the building's forecast operating energy needs.

Weather conditions with extreme temperatures will be analyzed to pre-dimension the heating and cooling capacities necessary to the smart living lab's good functioning.

A third weather data file will allow to simulate the 2050 climate in order to anticipate the evolution of the thermal reaction of the building in order to design it accordingly. SIA 2028 with "DRY warm" as Design Reference Years Warm is a weather data file for a climate change scenario with hot temperatures that could be used.

Develop a bioclimatic strategy

A bioclimatic strategy will be proposed in accordance with the user profiles and the external climate. This strategy will have as objective to propose a concept of architectural envelope which will allow to clip the climatic external variations for an internal climate closer to the smart living lab's range of comfort, as shown in Figure 23.

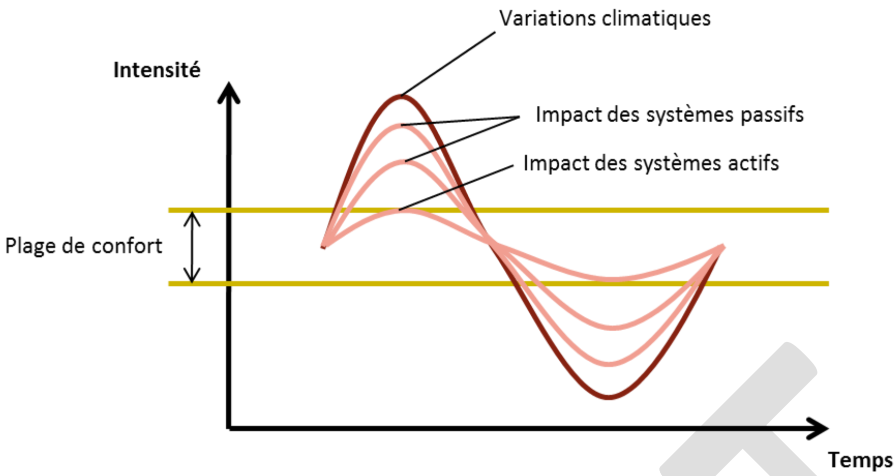

Figure 23 : Bioclimatism (exNdo Studio)

A spatial strategy will propose an adapted localization of different functional areas in order to reconcile human activity and external climate. For instance:

- Low occupancy areas will be located in the least favorable spaces
- Internal heat-gain areas will be located in minimal sun exposure spaces
- …

Calculating and optimizing need

The main bioclimatic parameters (Figure 24) will then be qualified with sensitivity analysis to allocate the maximum efforts on the most sensitive parameters of the thermic envelope.

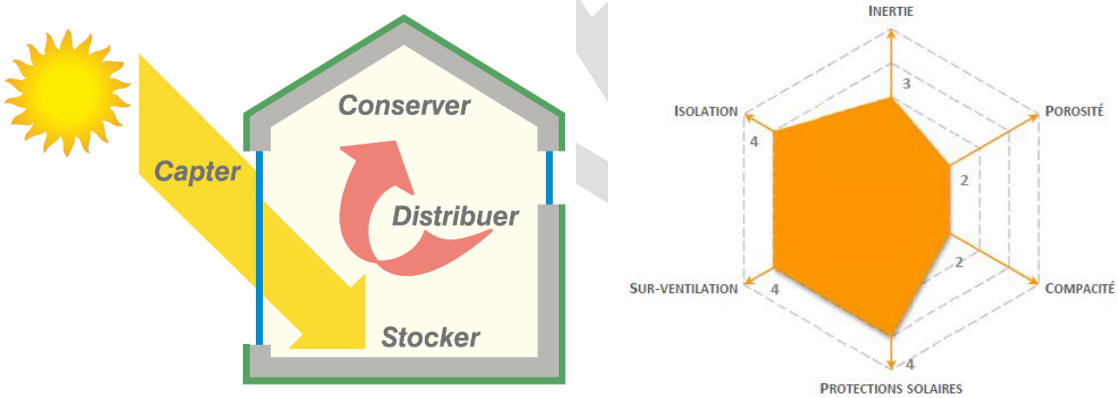

Figure 24 : bioclimatic levers (architecture and climate + exNdo Studio)

The best possible balance between embodied energy and need will have to be found.
Energy efficiency gains will be put into perspective in a life-cycle approach calculating the implemented embodied energy quantity regarding to the saved operating energy. The most efficient solutions represented by the target in Figure 25 will be considered.

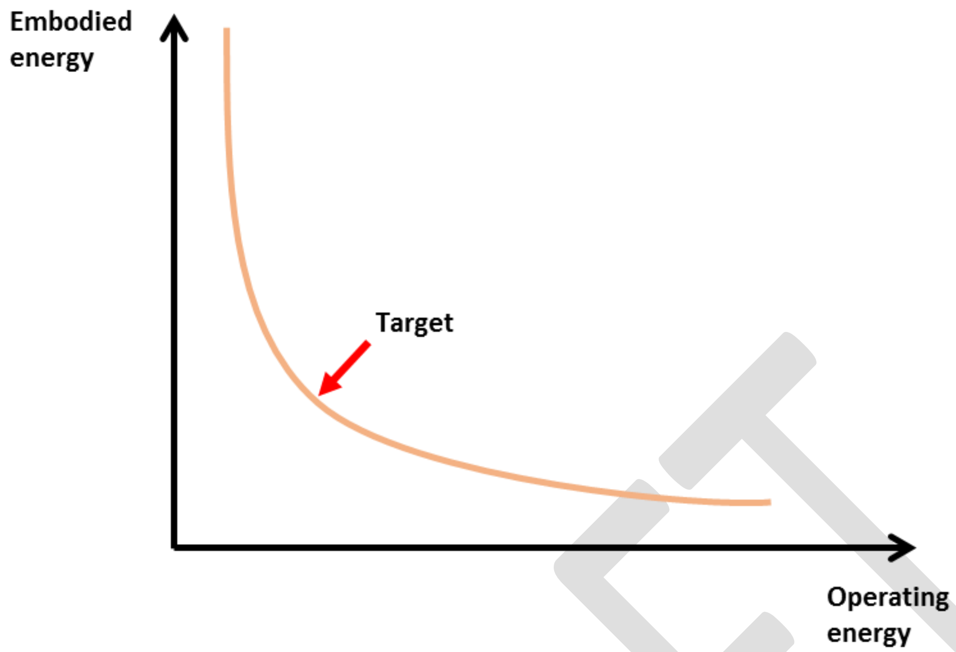

Figure 25 : operating energy vs embodied energy

This program will allow to answer the following questions:

1. At what point does insulation thickness become a disadvantage for the building?
2. At what point does the increase of thermal inertia due to the use of materials become a disadvantage for the building?
3. At what point does the increase of glass surface become a disadvantage for the building?

This approach will allow - within the smart living lab scientific program - to formalize a bioclimatic strategy, targeting the most life-cycle efficient parameters proper to the smart living lab activity.

A flexible bioclimatic strategy

In order to test the bioclimatic strategy robustness, 3 initial assumptions will change in specific studies:

- The external environmental climate will evolve to simulate the outlook 2050
- The internal environmental climate will evolve to simulate a change of use in the building
- The construction quality will be depreciated depending on the structure complexity and longevity

Parameters which are too sensitive to the evolution of these changes, will have to be specifically addressed in order not to invest embodied energy in an architectural envelope not efficient in the long term.
To step outside the theoretical framework, a complexity scale will have to be created in order to have an impact on the construction techniques that more accurately reflect the exploitation and construction conditions of a building.

5.5.4 Active energy systems

As a reminder, this research field is characterized by the $\frac{CO_2}{OEn}$ indicator, representing the carbon intensity of the energy demand. High energy conversion efficiency using a low-carbon source will have to be used in order to address the smart living lab requirements.
The target energy requirements as well as the carbon content of the primary energy consumed, will be fixed by allocated quotas within the framework of the LCA research field.

The available renewable energy sources will have to be qualified in order to meet the building energy needs. These needs and resources will have to be overlaid to be able to verify the correlation in time and thus assure a maximum self-sufficiency. The whole energy concept must be detailed in order to offer enough energy conversion efficiency to meet the needs using the limited resources available.

Quantification of on-site available energy resources

The identification of the available energy will be done thanks to an analysis of the site and its potential regarding renewable solar, hydro, wind, biomass and geothermal energy. These resources will be quantified and an energy production time-table scenario will be drawn-up.

In addition, the energy waste generated by human activity will be identified in order to evaluate eventual energy recovery possibilities. Likewise, these resources will be quantified and an energy production time-table scenario will be established.

Correlation need / resources

These available resources will have to be compared to the needs of the smart living lab, in order to best assess the ability to participate in the stability of the electrical grid by means of autonomy, self-sufficiency and direct control load management. In its 2012 report, the EPIA[21] expresses the need for electricity storage to better correlate needs and local energy production (Figure 26).

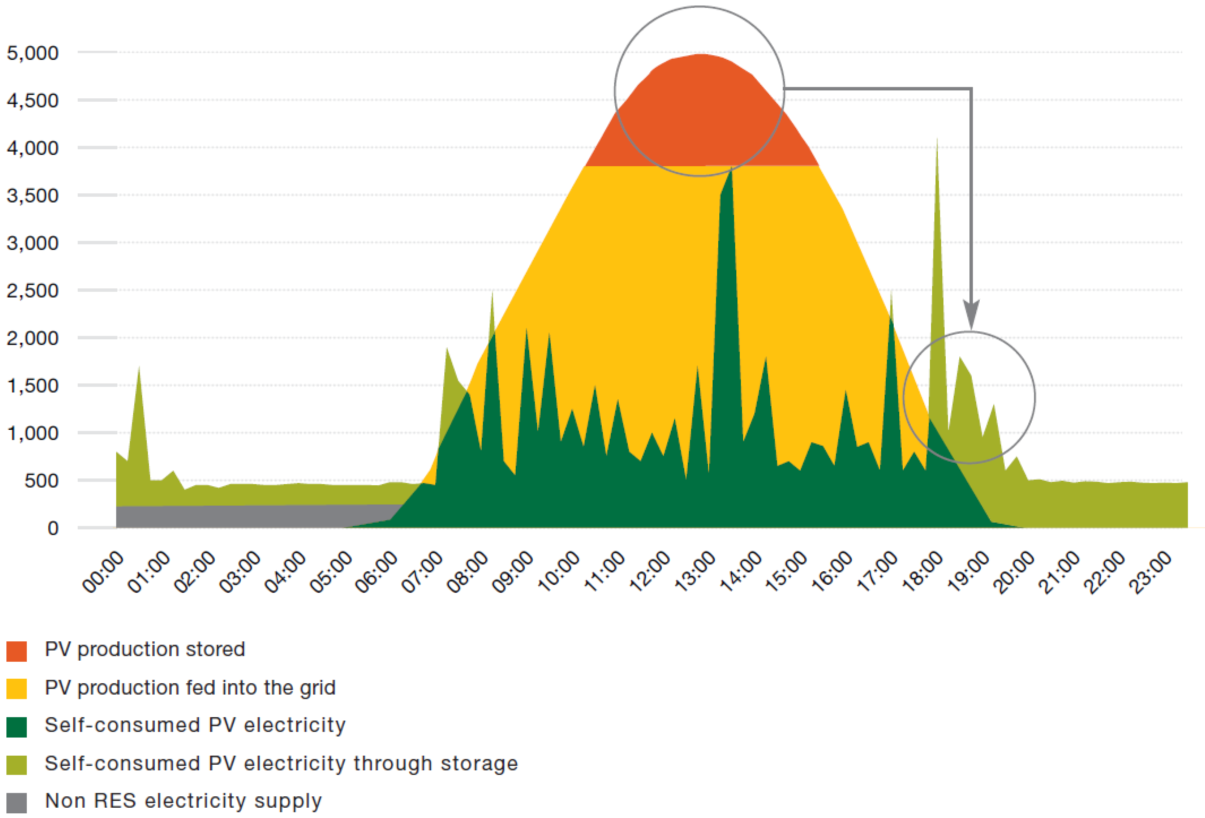

Figure 26 : Technical diagram on the logic of energy storage (EPIA)

It is necessary to address this issue for two main reasons:

- The carbon content of the electrical grid will be different according to the time the energy is used. Indeed, solar energy will always have a day/night cycle during its production. The building performance will

[21] European Photovoltaic Industry Association, « Solar photovoltaic on the road to large-scale grid integration » (Craig Winneker, 2012).

therefore be improved if it's capable of optimizing the consumption in relation to the energy carbon content.

- To reach a share of 50% of renewable energy in 2050 and of 75% in 2150, will be strongly conditioned by the capacity of energy needs to manage the peak load and the correlation with renewable energy production.

This work should lead to the sizing of renewable and storage installations, which will allow to supply the renewable energy content to better address the building's requirements.

Energy conversion and release

Based on the available resources, energy system strategies will have to be developed to meet the smart living lab requirements.

The energy concept will have to be compatible with the work undertaken under the research on flexibility to make the evolution of proposed spaces easier based on the lifespan of established systems or their predictable obsolescence.

All the technical elements which convert energy to meet the building's requirements will be concerned by this strategy. For example, lighting, heating, cooling, ventilation, hot water, IT and telecommunications equipment, elevators, etc…

This strategy will be implemented and evaluated by two thermodynamic laws. The first one, in order to limit the energy demand. The second one, from a qualitative point of view, to assess the losses due to entropy generation (exergy).

A special attention will be granted to the converted energy distribution, in order to assess the losses and to propose specific centralized or decentralized energy solutions.

The levers of the effectiveness of the energy concept will therefore be as follows:

- Carbon content of used energy sources
- Energy conversion efficiency
- Energy distribution efficiency
- Heat sources efficiency (radiator, under-floor heating, fan-convectors…)

Calculating and optimizing CO_2 emissions

These levers will be qualified by sensitivity analysis in order to put maximum efforts on the most sensitive parameters. The best possible balance between demand and carbon content of the used energy will have to be found.

The most efficient solutions will then be adopted.

This work will allow to answer the following questions:

- At what point does insulation pipes become a disadvantage for energy distribution?
- Is the technical installation complexity and quantity beneficial in view of the carbon content?
- …

This approach will formalize within the smart living lab scientific program an energy concept targeting the most efficient parameters on the life-cycle, specifically for the smart living lab activity.

A robust and flexible energy concept

As we can see in Figure 27 and Figure 28, based on results derived from a broad sample of about 90 buildings[22], the more the calculated heating energy demand is low, the more the measured value is far from the prediction. Moreover, the more the heating cost are low, the more the maintenance charges are expensive, that is to say, the global amount of charges (maintenance + heating) does not change whatever the performance of the building.

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[22] Walter Hüttler, « Cost optimal building standards–evidence based! The case of Austria », consulté le 26 novembre 2014, http://www.irbnet.de/daten/iconda/CIB_DC26262.pdf.

These two conclusions are directly linked to the complexity of the housing that are not built, or used, or maintained as expected.

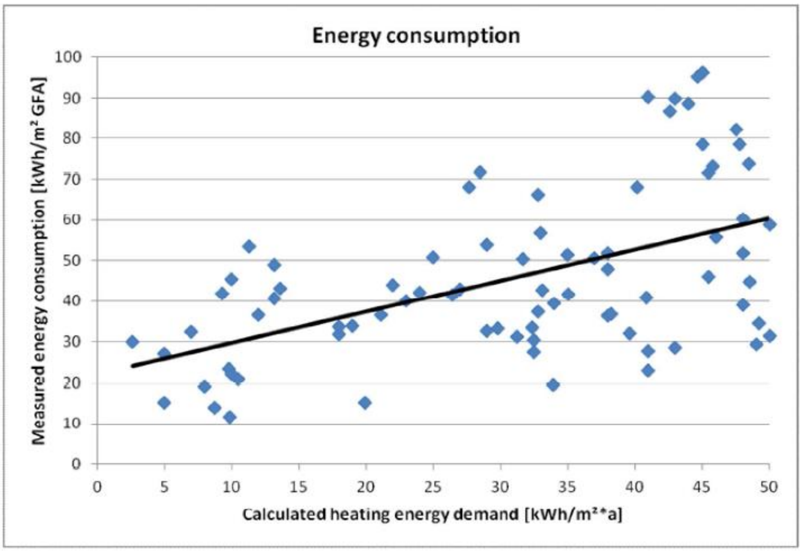


Figure 27 : Energy consumption for heating vs. calculated heating energy demand in nZE multi-family-residential buildings (Walter Hüttler, 2012)

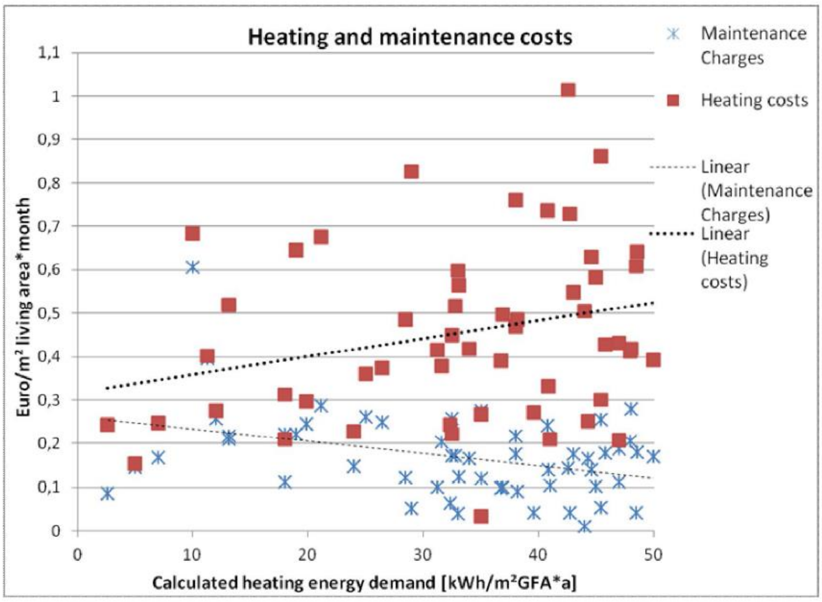


Figure 28 : Energy costs for heating and maintenance costs in nZE multi-family-residential buildings (Walter Hüttler, 2012)

The change of the two starting assumptions will allow to put the strength of the proposed strategy to the test:

- the proposed systems performance degradation according to their complexity from a maintenance point of view
- the performance degradation of the regulation and control of proposed systems according to their complexity from the users' point of view

Complexity scales will have to be created in order to have an impact on the theoretical performance of technical proposals. An electric heater, for instance, has a much lower theoretical performance compared to an absorption heat pump. Its simplicity is, on the other hand, much higher. It is therefore normal to correct the theoretical performance by a complexity factor.

5.5.5 The frontiers of research field

The four research fields and their actions are strongly linked and interdependent. In order to clarify the areas of research, the schematic diagram in Figure 29 shows the boundaries of every field.

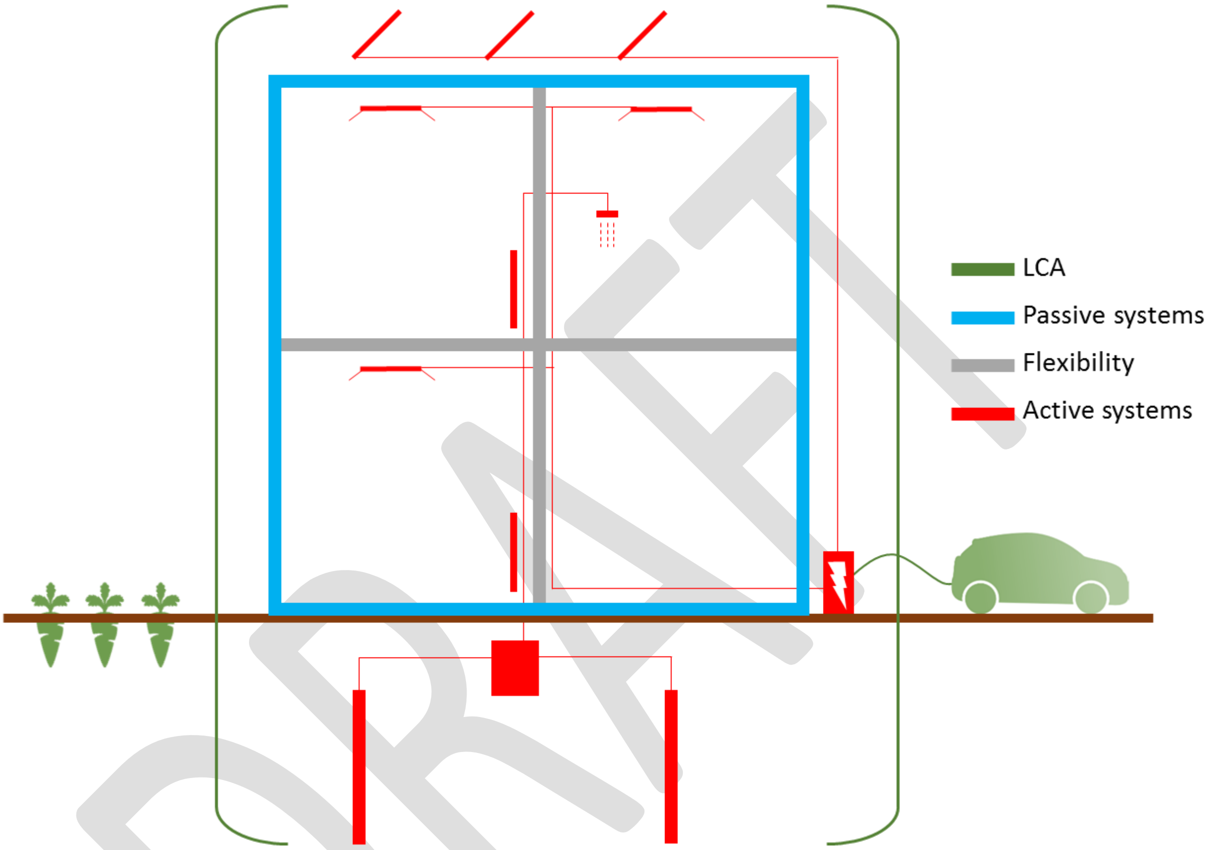


Figure 29 : Technical diagram of research field programs

5.6 Workshops

There will be three successive workshops that will test the strength of the scientific concept. These workshops will represent the transition between the concept and the scientific program which will specify the smart living lab performances.

5.6.1 Building maintenance Workshop

Objectives

Evaluating simplicity and robustness of the concept for an efficient building maintenance
Evaluating the operating cost regarding the maintenance budget
Development of new maintenance practices

Length

1 day in April 2015

5.6.2 Building construction workshop

Objectives

First contact with the construction companies
Implementing their last technical development into the concept
Evaluating the technical feasibility of the concept

Length
1 day in May 2015

5.6.3 Scientific workshop

Objectives
Evaluating the scientific concept with the best specialists
Enhancing the scientific credibility of the research program
Public conferences with the specialists

Length
1 week in June/July 2015

5.7 Experiments

The pilot phase is expected to make the scientific program reliable, testing its operability, in order to ensure the project's technical, economic and legal feasibility.
The technical and architectural concepts, which are subject to test, will be chosen during the review and validation phase of the scientific program. This selection will be done according to the following criteria:

- The importance of the concept within the resources used to guarantee the sustainability of the building
- The uncertainty regarding the technical feasibility
- The feasibility of the experiments within schedule and budget

Pilot phase will be conducted in three phases.

5.7.1 Preparation

Length: 1 to 2 months
The preparation phase will allow to clearly describe the expected performance, to validate the assumptions made and to assess the conditions for success or failure.
It will also be the occasion to describe and to draw the required installation to carry out the experiment.
The planning and implementation protocol will be submitted and will allow to ensure the smooth running of the experiment.

5.7.2 Realization

Length: 3 to 4 months
The realization will take the form of a physical experimentation on a 1:1 scale. The physical phenomena tested will therefore be as close to reality as possible and the developed prototypes will act as support of discussion with all the project's players: researchers, project owners, companies and designers.
The content and nature of the experiment, will strongly depend on the results of the scientific program, but a first assessment on the potential nature of these experiments will allow us to better understand and calibrate this experimental phase.
There will be four experimental projects, one for each post-doc.

Figure 30 © Solar Decathlon 2012- Team Rhône Alpes Canopea

These experiments will be carried out in the Blue Hall / BlueFACTORY Fribourg, together with the construction of the Swiss Living Challenge for the Solar Decathlon 2016.

5.7.3 Assessment

Length: 1 month

The assessment period will allow the questioning of the experimental method applied, of its realization conditions as well the reliability of the result.

This phase will also be the occasion to assess the economic and legal compatibility of different concepts in relation to the smart living lab project, with the help of construction experts.

This questioning and assessment will allow to judge the experiment performance in order to confirm, counter or modify the use of concepts within the definitive operational program.

At the end of this experiment phase, the scientific program will therefore be updated according to the results obtained.

5.8 Promoting the research program

Different ways of promotion will be used to communicate beyond the smart living lab stakeholders:

- Scientific articles, on specific issues developed within the program to reach the scientific community
- Professional publications, for an operational transfer of the knowledge,
- Conferences, especially during the scientific workshop.

6 Key players, roles and responsibilities

6.1 Research Team Building 2050

Mission

Set up and implement the present research program

Stakeholders

Thomas Jusselme, Head of the Building 2050 research program
Arianna Brambilla, Passive systems postdoc
Endrit Hoxha, LCA postdoc
Yingying Jiang, Flexibility postdoc
Moon Keun Kim, HVAC postdoc
Stefano Cozza, Master student

6.2 Research and operational coordination committee

Mission

Coordination between the smart living lab, the research program and the building project.

Frequency

Twice a month

Stakeholders

Anne-Claude Cosandey, Operational Director of the EPFL Fribourg Outpost
Noël Schneider, smart living lab Building project manager
Thomas Jusselme, Building 2050 project manager

6.3 Smart living BUILDING scientific committee

Mission

Scientific executive board for the Building 2050 research program
Critical supervision of the research program,
Validation of the 6 successive deliverables
Scientific inputs during and between committees

Frequency

Meeting every two months

Stakeholders

Ecole Polytechnique Fédérale de Lausanne :
Emmanuel Rey, Head of the Laboratory of Architecture and Sustainable Technologies LAST, Scientific committee President
Thomas Jusselme, Building 2050 project manager
Noël Schneider, smart living lab Building project manager
Anne-Claude Cosandey, Operational Director of the EPFL Fribourg Outpost
Marilyne Andersen, Dean ENAC EPFL
Alexandre Blanc, Associate Professor ENAC IA MANSLAB1
Thomas Keller, Full Professor ENAC IIC CCLAB
Jean-Louis Scartezzini, Full Professor ENAC IIC LESO-PB

Ecole d'Igénieurs et d'Architectes de Fribourg :
Jean-Philippe Bacher, Head of the smart living lab program for EIA
Jacques Bersier, Head of applied research and development (Ra&D)
Elena Lavinia – Niederhauser, Head of the iEnergy laboratory
Florinel Radu, Head of the TRANSFORM laboratory
Prof. Daia Zwicky, Civil Engineering professor at iTEC

Université de Fribourg :
Stephanie Teufel, UniFR Head IIMT, Dean SES Faculty, smart living lab manager
Dennis Lalanne, Senior researcher
Jean-Baptiste Zufferey, Administrative Law Professor
Peter Richner, Deputy Director EMPA

6.4 Smart living research academic committee

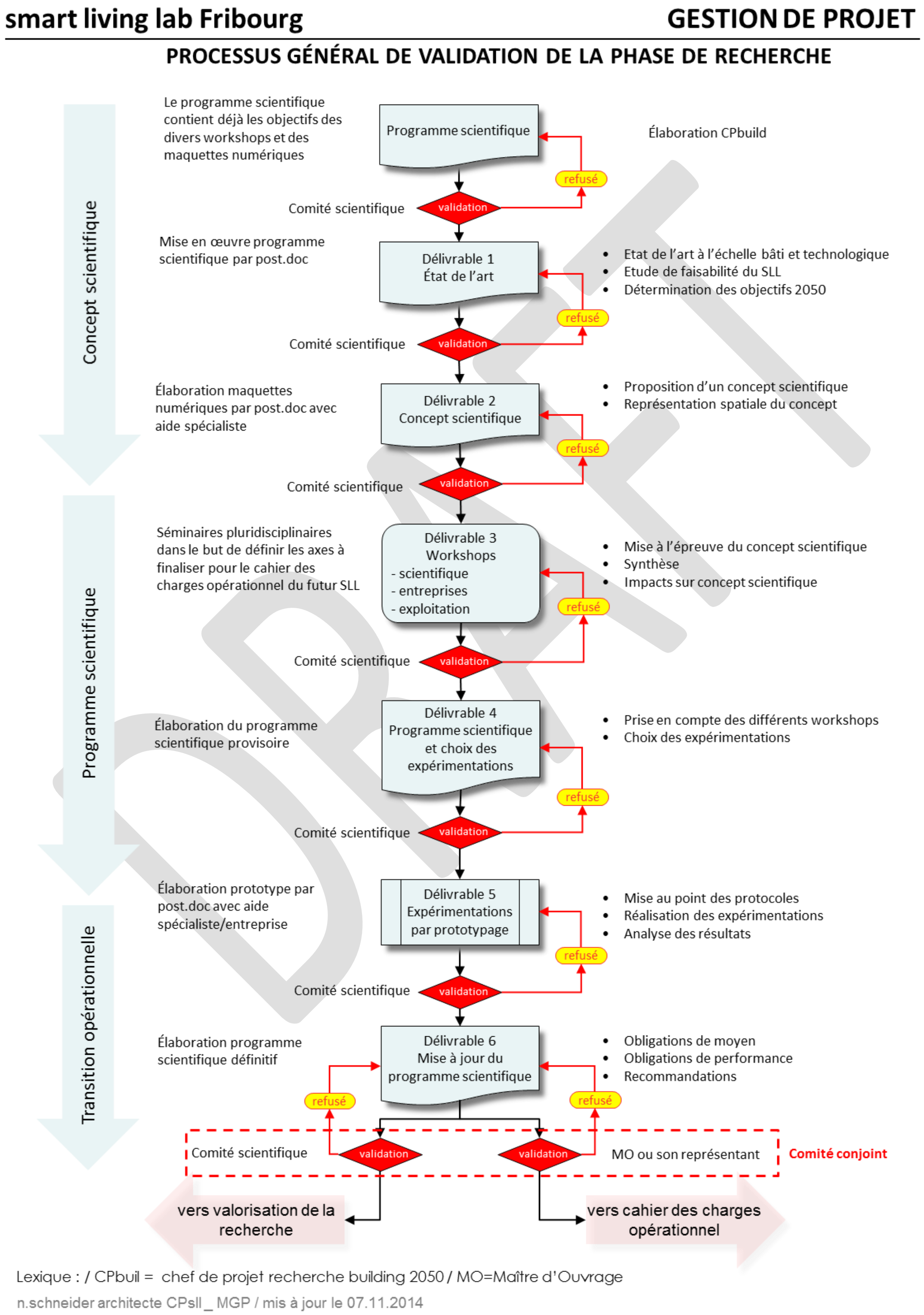
Mission
Academic advisory board for the Building 2050 research program
Academic supervision of the research, methodology and scientific publications

Frequency
Meeting every two months

Stakeholders
Marilyne Andersen, Dean ENAC EPFL, Head of the Interdisciplinary Laboratory of Performance-Integrated Design
Thomas Jusselme, Building 2050 project manager
Anne-Claude Cosandey, Operational Director of the EPFL Fribourg Outpost
Emmanuel Rey, Head of the Laboratory of Architecture and Sustainable Technologies
4 postdoc positions

7 Deliverables

6 successive deliverables will be produced by the research group. All of them will have to be validated by the scientific committee following this process:

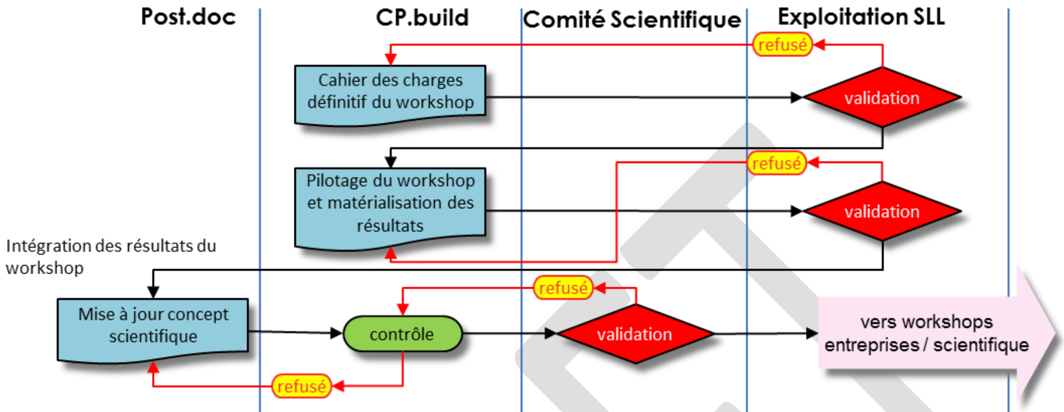


Processus détaillé des validations : workshops (délivrable 3 réf. processus global)

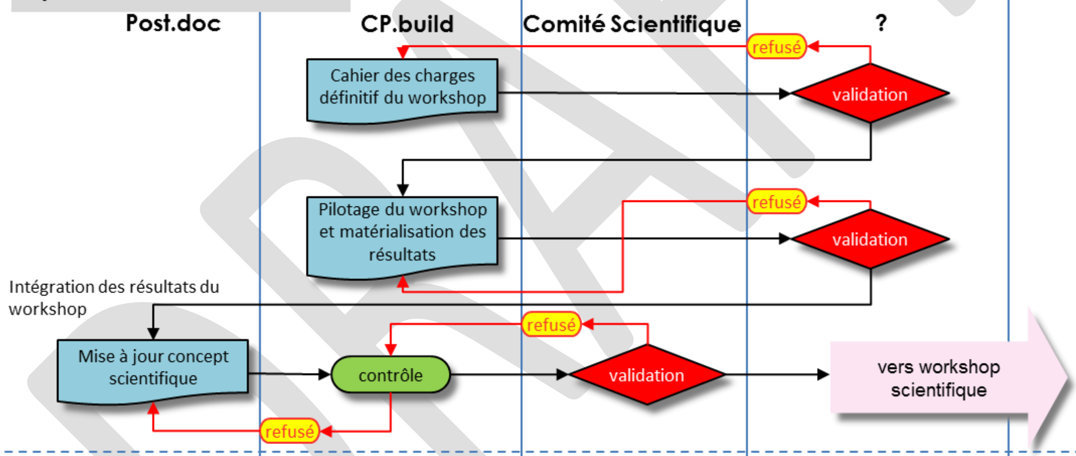
1) Workshop exploitation / maintenance (avril 2015)
2) Workshop entreprises (mai 2015)
3) Workshop scientifique (juin-juillet 2015)

Le concept ainsi que les objectifs stratégiques des workshops sont déjà intégrés et définis dans le programme scientifique

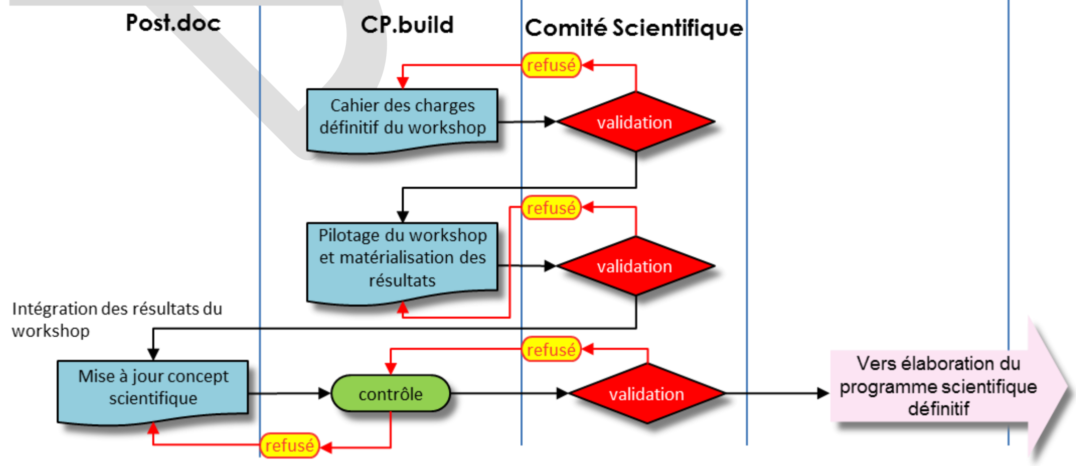
1) Workshop exploitation / maintenance



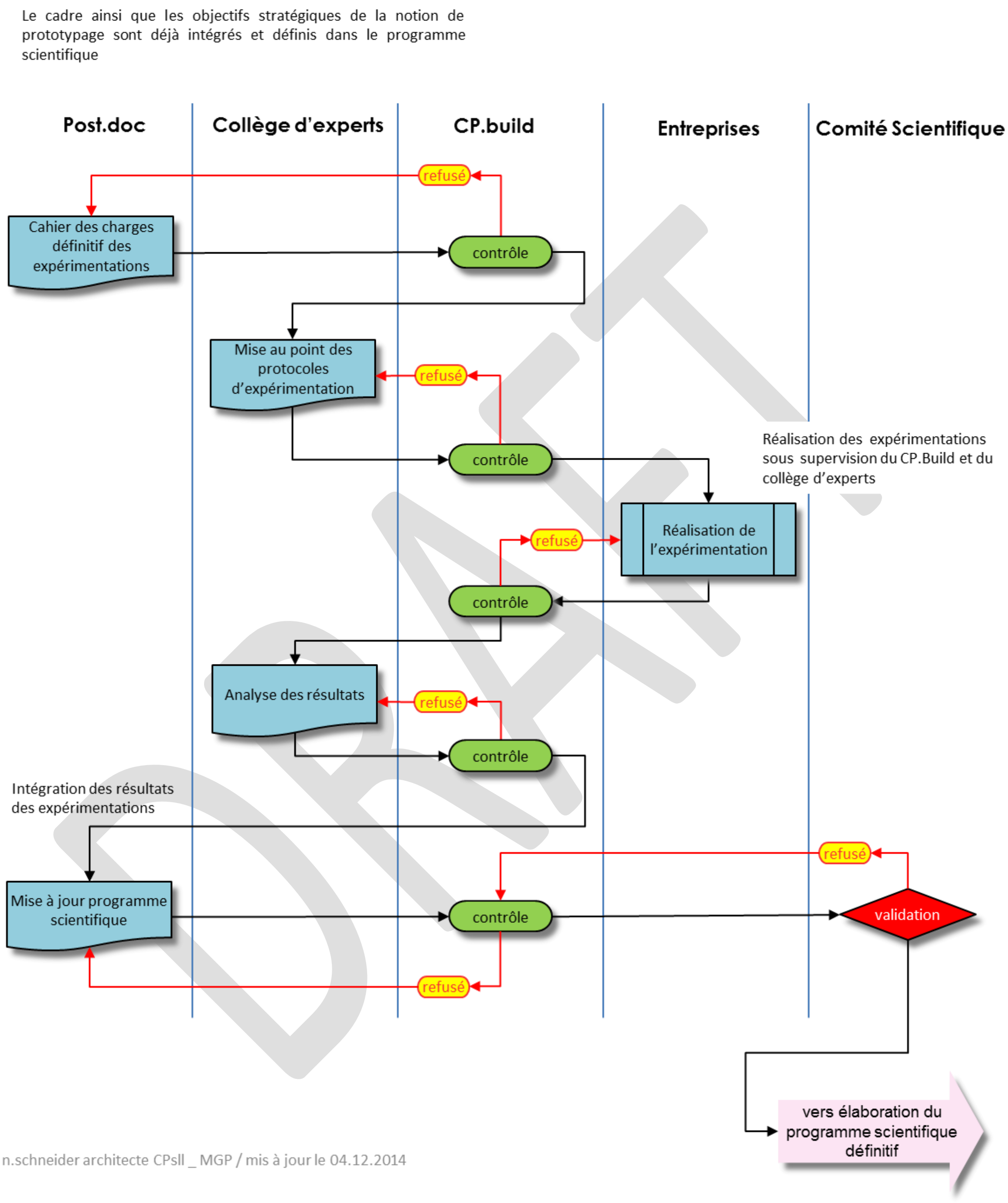
2) Workshop entreprises



3) Workshop scientifique



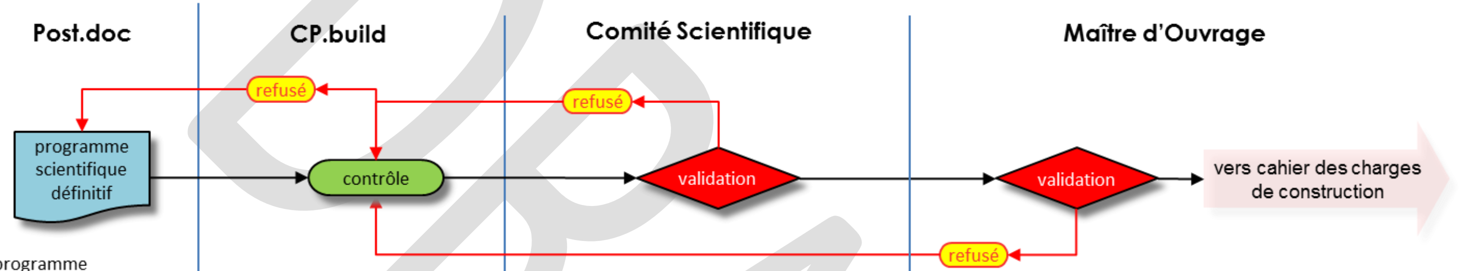
PROCESSUS DÉTAILLÉ DES VALIDATIONS : PROTOTYPAGE (délivrable 5 réf. processus global)



n.schneider architecte CPsll _ MGP / mis à jour le 04.12.2014

PROCESSUS DÉTAILLÉ DES VALIDATIONS

VALIDATION DU PROGRAMME SCIENTIFIQUE DÉFINITIF (délivrable 6 réf. processus global)

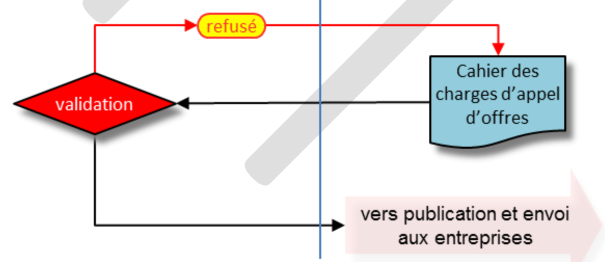


Elaboration du programme scientifique définitif sur la base des résultats de l'expérimentation par prototypage

VALIDATION DU CAHIER DES CHARGES DE L'APPEL D'OFFRE POUR LA CONSTRUCTION DU SLL

Commission de construction

Commission de construction composée d'une part des utilisateurs et d'autre part de représentants du comité scientifique permettant de confirmer à la fois les besoins et l'application du contenu du programme scientifique



Elaboration du cahier des charges d'appel d'offres par le MO ou son représentant sur la base du programme scientifique validé

Envoi du cahier des charges d'appel d'offres aux entreprises par MO ou son représentant.
Définition de la suite de la procédure d'analyse des offres et d'adjudication

n.schneider architecte CPsll _ MGP / mis à jour le 21.11.2014

8 Planning

The Building 2050 research program started in September 2014 and will end in September 2016, that is to say a two-year period. The major milestones are described in the following table:

	Deadline	**Length**
Research program definition	Nov. 2014	2 months
State-of-the-art	Mar. 2015	2-4 months
Scientific concept	July 2015	4 months
Workshops	July 2015	1day / 1 week
Scientific program	Oct. 2015	3 months
Experiments / Prototypes	April 2016	6 months
Update of the scientific program	May 2016	1 month
Promote the research	Sept. 2016	3 months
Submission / Design / Construction	Jan. 2020	3 years

An operational and detailed planning for each phase will be set up.