

Comparison of Strategies improving Local Energy Self-sufficiency at Neighborhood Scale. Case study in Yverdon-les-Bains (Switzerland)

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ABSTRACT

Within a context of growing efforts to develop sustainability strategies, one of the main challenges is promoting value creation while using fewer resources. In this perspective, how can we design attractive urban neighborhoods generating endogenous economic activity and fostering socio-cultural dynamics, while moving towards local energy self-sufficiency? Answering that question requires major changes in the way we consider energy in the construction sector, by thinking beyond the scale of a single building and by including a greater number of design parameters. Filling this gap in current research, the Symbiotic Districts project examines dimensions influencing energy self-sufficiency at neighborhood scale by integrating parameters related to buildings, infrastructure, mobility, food, goods and services.

The present paper analyzes the results of a case study on an urban sector in the city of Yverdon-les-Bains (Switzerland). Taking lifestyles as a starting point, the project explores three scenarios (technological, behavioral and symbiotic) for the future development of this neighborhood for 2035. The scenarios test different design strategies related to industrial symbioses, production, storage, transportation or urban agriculture. In order to calculate an estimated global balance, an energy flow analysis allows the assessment and comparison of the energy performance of each scenario. In parallel, an urban form adapted to the proposed vision evaluates how architectural and urban design is likely to foster the necessary behavior changes towards the expected energy turnaround.

1 INTRODUCTION

Within a context of a growing efforts to create sustainable development strategies, a wide array of research programs are being conducted on energy-related issues in the built environment. And for good reason: over 40% of worldwide energy consumption can be attributed to the construction sector (Wallbaum, 2012). In Switzerland, a landscape dense with urban development, total energy expenditures associated with buildings account for no less than half of total energy consumption (Zimmermann, Althaus, & Haas, 2005). Ambitious objectives to reduce renewable and non-renewable energy consumption are now being set by several European countries, following the example of the 2000-Watt Society concept developed in Switzerland or the political vision of phasing out nuclear energy over the medium-term (Jochem, 2004; Previdoli, 2012).

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At the same time, the projected end of abundant low-cost fossil fuels, geopolitical tensions around the issue of natural resources and the vulnerability of electrical power grids are all factors that encourage finding more secure energy supply strategies, particularly by making use of local resources. With this objective in mind, working towards local energy self-sufficiency – and specifically a balance between the energy consumption of a territory and its ability to meet its own demand through sustainable production – will allow us to minimize environmental impacts while at the same time generating endogenous economic activity and promoting a social and cultural dynamic in which the users can become involved. This type of approach requires a significant reduction in demand (moderation), the widespread use of renewable energy (local production), and an effort to achieve complementarities between operation (industrial symbiosis) and on-site energy storage (Grospart, 2009).

Taking these matters into account requires major changes in the way we consider energy in the construction sector, firstly by clearly transcending the scale of the single building in order to address urban reality at neighborhood scale (Rey, Lufkin, Renaud, & Perret, 2013). This intermediate scale reveals some surprising information. On one hand, it is broad enough to address themes that transcend the single building, opening up possibilities for studying interactions between these entities. On the other hand, unlike city scale, on which most of the current research on local energy self-sufficiency focuses, it is restricted enough to design, test and examine concrete and operational initiatives (Rey, 2011). Therefore, this approach allows taking into account multi-functionality, considering certain industrial activities and urban or suburban agriculture activities near residential areas, while keeping them to the appropriate scale for the most strategic approaches to urban development (e.g. master plan).

Secondly, a greater number of design parameters needs to be included in the reflection, moving well beyond basic issues related to the buildings' heat and electricity consumption. The observation of the traditional neighborhood highlights the limitations of its urban flows operational scheme. This urban metabolism, which can be described as linear, requires large amounts of external inputs, largely stemming from non-renewable sources, and generates a high level of non-valorized rejects (waste, greenhouse gas, dissemination into the environment or liquid effluents). In addition, interactions between the functions are very limited. This system increases the neighborhood's ecological footprint and could potentially challenge its very existence over the long term.

To work towards greater sustainability, new modalities are therefore needed to increase both the self-sufficiency and efficiency of urban environments. In reaction, the Symbiotic District project was conceived in order to promote a "syntropic" urban system, i.e. a mature ecosystem capable of fostering cities' economic and sociocultural development, while making the best use of imported resources and limiting waste production thanks to a circular metabolism. Concretely, such an approach embraces industrial ecology principles (Erkman, 1998) and aims at transposing them to the built environment in general, and the Swiss urban context in particular. The Symbiotic District project simultaneously examines scientific, technical, urban development and architectural aspects of local energy self-sufficiency at neighbourhood scale by integrating issues related to buildings, infrastructure, mobility, goods, services and food (Lufkin, Rey, & Erkman, 2014). The approach relies on three complementary optimization strategies: increasing the city's intrinsic efficiency, valorizing renewable energy sources and implementing urban symbioses (Lufkin, Rey, & Erkman, 2013).

The research also aims at identifying the most relevant levers to reduce energy consumption - lifestyles, technology or urban form - and studying interactions between these lines of action. Indeed, in spite of increased consciousness about energy issues, private or public stakeholders find it difficult to commit to a responsible behavior due to the absence of sufficiently accurate information. Establishing a reliable basis to address energy issues in future sustainable urban neighborhoods (in the horizon 2035), the approach provides a systematic exploration of the links, still to be created, between strictly quantitative aspects related to energy self-sufficiency (stemming from industrial ecology) and qualitative and operational aspects related to their implementation into urban and architectural projects (Erkman, 1998).

2 STATE OF THE ART

The idea of considering city as an ecosystem is not new. It was introduced in the sixties, in particular by biologists, who started drawing their inspiration from the theory of ecosystems in order to deal with the complexity of the environment and to understand it in a more systematic way. Deriving from these reflections, urban metabolism provides sound methodological and practical tools to analyze urban resources and flows (Baccini, 1996; Newman, 1999). Applying this approach to cities, researchers started highlighting a number of dysfunctions: high dependency towards fossil energy, low efficiency due to linear processes, inefficiency of sectoral policies and "end of pipe" solutions, etc. (Barles, 2008; Dobbelsteen, Keeffe, Tillie, & Roggema, 2012). Urban metabolism is a very efficient approach to assess a region's or a city's level of sustainability and to identify resources and waste potentially reusable at regional scale (Codoban & Kennedy, 2008). However, territorial or urban scale remains too large to transpose the results from such a model to strategic operational processes.

To date, attempts to apply urban metabolism at neighborhood scale are few and very recent. Indeed, the parameters usually considered in research and practice rarely go beyond the building's energy consumption (heating, domestic hot water, electricity, grey energy). A limited number of experiences try to include aspects related to the inhabitants' transportation and food in a broad perspective, addressing energy supply as both an energy consideration – power supply accounts for a significant portion of the total energy balance per inhabitant (Rey, 2006) – and from an urban development standpoint – urban agriculture, for instance, is becoming an increasingly popular consideration with regard to achieving urban sustainability (Gorgolewski, Komisar, & Nasr, 2011; Jourdan & Mirenowicz, 2011).

These examples include the REAP methodology in Rotterdam (Tillie et al., 2009), the Amsterdam Guide to Energetic Urban Planning (Tillie, Kürschner, Mantel, & Hackvoort, 2011), the Urban Harvest Concept in Kerkade West (Agudelo-Vera, Leduc, Mels, & Rijnaarts, 2012) and the New Stepped Strategy (Dobbelsteen, 2008). These references speak to the benefits of combining different functions within the same neighborhood or even within the same building, thus revisiting a "fine-grained" functional mix. All these pilot projects are still at experimentation or planning phases, none of them has yet been realized. Today, the main challenge is their integration into a consistent and realistic reflection in order to positively influence local energy and resource self-sufficiency at neighborhood scale.

3 METHODOLOGY

In reaction, the case study presented in this paper focuses on the Gare-Lac sector in Yverdon-les-Bains (Switzerland). The site is currently a large urban wasteland of about 23 hectares, strategically situated between the railway tracks and Lake Neuchâtel, in very close proximity to the station and the city center. The local master plan (PDL) (Bauart Architectes et Urbanistes SA, 2010), currently under validation, was used as a basis for the present case study. The research is conducted in four stages:

1 - Energy cadaster Making an inventory of available local resources, the first stage establishes a regional energy cadaster. Renewable energy production installations and supply projects situated within the perimeter of the urban region of Yverdon are listed. The resulting local energy mapping takes into consideration resources such as biomass, sun, wind, waste heat, geothermal potential, lake, etc.

2 - Scenarios Based on this cadaster and on the recent PDL, three radical scenarios (technological, behavioral and symbiotic) are developed in a 2035 perspective. Enriched by prospective reflections on the evolution of European lifestyles (IDDRI, 2012), the scenarios embody a specific positioning to meet sustainability concerns. Set by the PDL, the human density (number of inhabitants and jobs per hectare) is the same for all scenarios, i.e. 3'810 inhabitants and 1'260 jobs. The built density (gross floor area, GFA), however, varies from one scenario to the other, mainly because of the variation of average per capita living space and the type of activity.

3 - Energy flow analyses For each scenario, several hypotheses are then formulated. They are structured into five domains, which contain a variable number of categories and sub-categories:

Table 1. Summary List of the five domains and their respective categories

Buildings	Mobility	Infrastructure	Food	Goods and services
Construction	Car	Neighborhood /	Agriculture	Clothes
Domestic hot water	Airplane	municipal facilities	Transformation	Furniture
Heating/Ventilation	Train	External installations	Packaging	Restaurant
Lights and devices	Other	Other	Distribution	Hotel / Leisure

Three indicators are calculated in order to analyze the energy consumption of each scenario: Total Primary Energy (TPE), Non-renewable Primary Energy (NRPE) and Global Warming Potential (GWP). The first step is the evaluation of the current situation, which serves as reference point. Users behavior and habits are based on the current Swiss average. Each (sub)-category value is then adapted according to the scenario's specific hypotheses.

4 - Urban form In parallel, an urban form is proposed for each scenario (Fig. 1-3). It is developed according to the lifestyle assumptions on which the scenario is based and provides a visualization of the future neighborhood. Indeed, each lifestyle reflects distinct uses, which correspond to specific needs in terms of spatial, functional and sensitive qualities (Thomas, 2011). This transposition of conceptual assumptions into an urban form also assesses the extent to which urban and architectural quality is likely to promote behavioral changes necessary for a transition towards a more sustainable society.

4 RESULTS

4.1 Local resources

The identified local resources are attributed to the Gare-Lac neighborhood according to a principle of territorial representativeness. For instance, if a resource is shared by the whole urban region (or the city) of Yverdon-les-Bains, only 7% (respectively 14%) of this potential is allocated to the site. This percentage corresponds to the ratio between the site's population and that of the considered territory.

Waste heat The public baths of Yverdon, whose water is heated to 32°C, and the water treatment plant are the major installations likely to contribute to local symbioses through a process of waste heat recovery. The combination of these two sources could potentially produce 3.5 thermal MW. Due to the proximity of these installations to the site, it was decided to allocate 30% of this potential to the new neighborhood.

Geothermal potential According to information provided by the Commune of Yverdon-les-Bains, a geothermal cogeneration project should be completed in 2017. It represents a potential of 5 electric MW and 60 thermal MW, of which 14% are allotted to the new neighborhood.

Biomass It was estimated that organic waste produced by the inhabitants of the neighborhood and the animals living in the vicinity could produce as much as 114 electric kW thanks to heat-power coupling generated by agriculture biogas. In addition, a wood-energy plant is being studied. The latter could potentially produce 17 thermal MW, of which 14% would be allotted to the Gare-Lac sector.

Solar potential The SEY have planned a photovoltaic supply growth of 0.5 MW per year until 2035, i.e. a total growth of 13 MW including the existing capacity. In a similar way as biomass and geothermal potential, 14% of the stock is attributed to the future neighborhood.

Wind potential Two major wind power projects are being considered in the Northern Vaud region, totaling 39.5 electrical MW. Considering this scale, only 7 % of this energy will be distributed to the neighborhood, i.e. 2.8 electric MW.

Lake Neuchâtel In spite of the important potential of the lake, it has not been considered as a thermal resource for the sake of realism. For environmental reasons, this option is not desired by cantonal and communal authorities of the urban region of Yverdon-les-Bains.

The following table provides a summary of the available local resources, which are then allocated to the future neighborhood according to the hypotheses formulated by each scenario:

Table 2. Summary List of the local resources available

Resource	Waste heat	Geothermal	Biomass	Sun	Wind
Thermal [MW]	3.5	60	17	-	-
Electric [MW]	-	5	0.1	13	39.5
Percentage attributed to site	30 %	14 %	14 %	14 %	7 %

4.2 Performance of the scenarios

Technologic scenario Using the most advanced technologies to reduce energy consumption, this scenario doesn't imply any modification of the user's behavior. Overall, the environmental impacts decrease thanks to the improvement of the devices' efficiency, but this effect is counterbalanced by the general higher consumption. Main characteristics of this scenario are: Minergie A standard for all buildings, heavy construction mode, integration of renewable energies, increased average per capita living space (60 m² per person instead of the current 50 m²), stabilization of travelled kilometers, hydrogen-powered cars (for 50% of the users), imported, transformed and conditioned food, etc.

Table 3. Synthetic chart of the performance of the technologic scenario

Domain	TPE [W/pers]	NRPE [W/pers]	GWP [kg CO ₂ eq/year]
Buildings	642	428	914
Mobility	2'299	1'199	2'238
Infrastructure	551	491	603
Food	720	663	1'638
Goods and services	750	690	1'012
Total	4'962	3'471	6'405

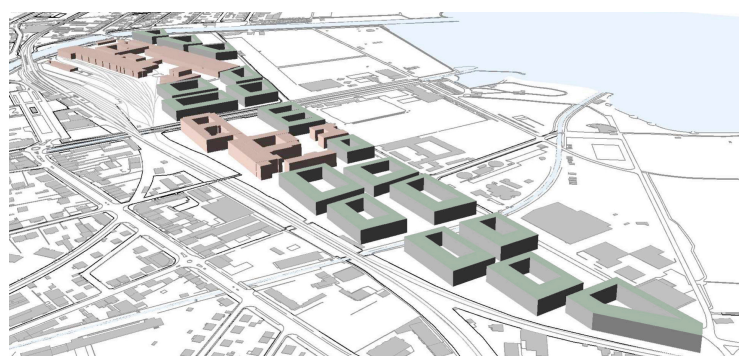


Figure 1 Visualization of the technologic scenario. Roofs' volumetries have been optimized in order to integrate photovoltaic panels (in green).

- Inhabitants: 3'810;
- Jobs: 1'260
- GFA: 260'100 m²

Behavioral scenario This scenario takes the opposite view and relies mainly on a change in users' behavior towards more frugal consumption, sobriety, simplicity, reduced consumerism and decelerating lifestyles. Thus, the driving force of the energy transition is mostly the demand reduction thanks to the modification of current social practices (energy supply by biogas and wood-energy plant, light wooden constructions, pooling of facilities, diminution of the average per capita living space to 40m² per person, increased soft mobility, increased car occupancy through car sharing, urban farming, natural treatment for public spaces, vegetarian, local and organic diets, autonomous production of goods and services, etc.)

Table 4. Synthetic chart of the performance of the behavioral scenario

Domain	TPE [W/pers]	NRPE [W/pers]	GWP [kg CO ₂ eq/year]
Buildings	651	449	400
Mobility	1'483	1'353	2'515
Infrastructure	508	479	578
Food	406	373	923
Goods and services	638	587	860
Total	3'685	3'240	5'275

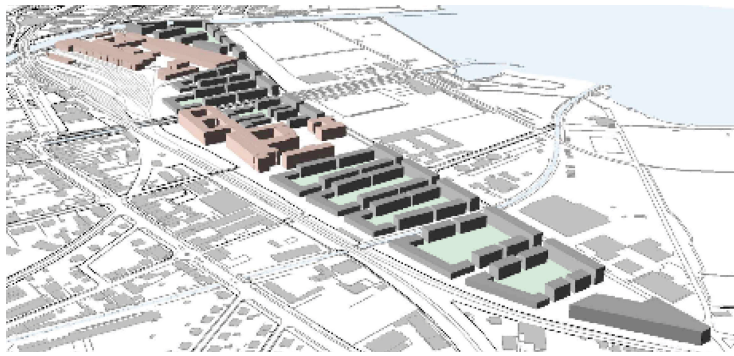


Figure 2 Visualization of the behavioral scenario. Large garden dedicated to urban farming are also special meeting places for the inhabitants (in green).

- Inhabitants: 3'810;
- Jobs: 1'260;
- GFA: 209'100 m²

Symbiotic scenario This scenario promotes urban and industrial symbioses opportunities to reduce the environmental impact of the neighborhood. Energy exchanges are implemented at all scales (building, group of buildings, neighborhood and between the neighborhood and its surrounding perimeter). The symbiotic scenario implies changes in behavior, but not as radical as the ones required by the behavioral scenario: users take responsibility toward sustainability and foster network and partnership dynamics. The main features of this scenario include: energy mainly supplied by heat recovered from the public baths and water treatment plant (3,4 thermal [MW] and 0.1 electrical [MW]), Minergie P standard for new constructions, recycled materials, heat recovery on waste domestic water and ventilation, stabilization of the average per capita living space (50m² per person), significant functional diversity (crafts and non-polluting industries), smaller and lighter vehicles, biodiesel for cars, development of the public transport network, diminution of air travels, healthy and responsible diet (reduced meat consumption, local and seasonal products), recyclable or repairable goods).

Table 5. Synthetic chart of the performance of the symbiotic scenario

Domain	TPE [W/pers]	NRPE [W/pers]	GWP [kg CO ₂ eq/year]
Buildings	778	690	731
Mobility	1'307	1'187	2'015
Infrastructure	543	513	611
Food	653	600	1'485
Goods and services	675	621	911
Total	4'005	3'654	5'775

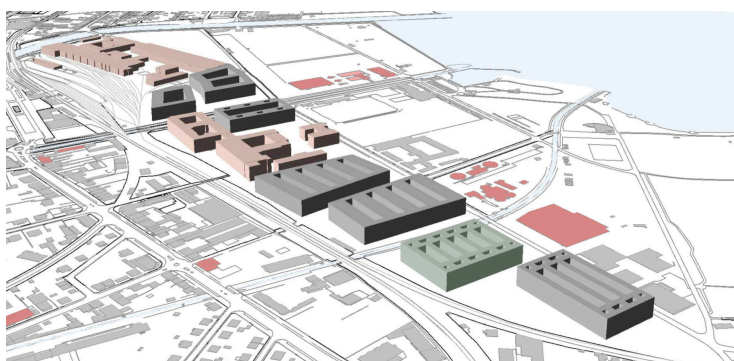


Figure 3 Visualization of the symbiotic scenario. Large urban blocks encourage short-distance exchanges at building and neighborhood scale.

- Inhabitants: 3'810;
- Jobs: 1'260;
- GFA: 262'320 m²

4.3 Discussion of the results

First of all, the energy consumption of all three scenarios is lower than that of the current situation (Figure 4). Besides, the ranking is rather immediate: for all indicators, the behavioral scenario appears as the most performing, and the technologic scenario is the most energy intensive (except for NRPE). However, these results need to be contrasted with the fact that only energy-related aspects were integrated into the assessment. Other criteria, in relation to social (acceptance), economic (costs of the implemented technologies) or environmental impacts, would be necessary in order to establish a more complete and global evaluation of the scenarios. For instance, the radical and very restrictive vision

embodied by the behavioral scenario is not fully realistic because of all the constraints imposed on the inhabitants' individual freedom. This remark highlights the relevance of holistic approaches, which form the core concept of sustainable development.

Nevertheless, the three indicators bring to light certain interesting phenomena. Concerning buildings, for instance, results are counter-intuitive: the buildings with the lowest energy consumption – those of the behavioral scenario – comply with the least strict construction standard. The explanation is provided by two factors: the average per capita living space and the construction modes. In the behavioral scenario, the reduction of living space to 40 m² per person (compared to the current 50 m²) leads to a diminution of approx. 30% of the necessary GFA in the neighborhood, which significantly influences construction and operation energy. In addition, light wooden constructions have a positive impact on the buildings' grey energy (as opposed to the heavy constructions of the technologic scenario).

Mobility also plays an important role in the energy balance of the scenarios. In the technologic scenario, mobility represents approximately half of the TPE. Its impact decreases a lot for the NRPE, thanks to the use of hydrogen-powered cars. In the behavioral scenario, the use of conventional cars penalizes the balance in spite of the absolute reduction of kilometers travelled. The symbiotic scenario offers the most convincing solution by encouraging simultaneously the use of collective transports and of biodiesel and electric cars (produced from renewable sources).

Regarding food, the most significant levers are related to reduced meat consumption. However, the impact of this change of eating behavior on the global balance remains low. From a strictly energetic point of view, this effort is of minimal benefit while a transition towards a vegetarian diet implies a high level of commitment of the inhabitants.

5 CONCLUSIONS AND FUTURE PERSPECTIVES

In order to put this reflection in perspective with long-term sustainability objectives pursued by several countries, Switzerland in particular, the results were confronted to the intermediary goals of the 2'000 Watts society concept for 2035 (Jochem, 2004). Figure 4 shows that none of the radical scenarios meets the targets for all three indicators. TPE values of both the behavioral and symbiotic scenarios are below the threshold of 4'400 [W/pers], while the technologic vision exceeds the limit. For NRPE, results of the three scenarios are all slightly above the objective of 3'300 [W/pers]. However, considering the uncertainties affecting some of the data, it can be considered that these orders of magnitude are roughly equivalent. CO₂ emissions of the three scenarios, by contrast, clearly exceed the intermediary target of 3,2 [tons CO₂eq/year]. This can be explained in part by the pessimism of the assumptions on which calculations of the flow analyses were made. In the next few years, technological innovations can be expected to improve efficiency and reduce losses of the systems. In relative terms, greenhouse gases emissions should therefore decrease more than absolute fuel consumption. However, these complex developments are difficult to forecast and would require a more in-depth analysis, which goes beyond the scope of the present research.

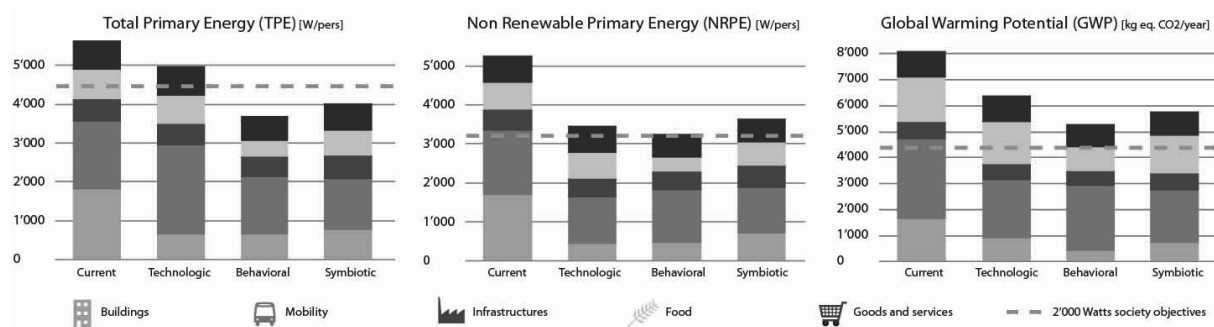


Figure 4 Histograms showing the comparative results of the current situation and the three scenarios, as well as the confrontation to the 2'000 Watts society objectives.

This confrontation to the 2'000 Watts society targets illustrates that no single strategy can work on its own to move societies towards a global energy transition. The behavioral scenario, which appears at first view as the better candidate, raises a series of questions in terms of acceptance and future oppositions. The energy consumption of the technologic scenario remains too high – not to speak about unresolved problems of economic feasibility. The same doubts can be expressed with respect to the symbiotic scenario, which would require intense political backing and educational support in order to translate the opportunities offered by urban symbioses into real achievements. Accordingly, a balance needs to be achieved by merging these strategies. It is precisely the objective of the future stages of the present research, which will explore this middle way approach by developing integrated scenarios, combining technological innovation, changes of lifestyle and short-distance exchanges.

REFERENCES

- Agudelo-Vera, C. M., Leduc, W. R. W. A., Mels, A. R., & Rijnaarts, H. H. M. (2012). Harvesting urban resources towards more resilient cities. *Resources, Conservation and Recycling*, 64(0), 3–12.
- Baccini, P. (1996). Understanding Regional Metabolism for a Sustainable Development of Urban Systems. *ESPR Environ. Sci. & Pollut. Res.*, 3(2), 108–111.
- Barles, S. (2008). Comprendre et maîtriser le métabolisme urbain et l’empreinte environnementale des villes. *RESPONSABILITÉ & ENVIRONNEMENT*, N° 52, 21–26.
- Bauart Architectes et Urbanistes SA. (2010). Commune d’Yverdon-les-Bains, PDL Gare-Lac.
- Codoban, N., & Kennedy, C. A. (2008). Metabolism of Neighborhoods. *Journal of Urban Planning and Development*, (March), 21–31.
- Dobbelsteen, A. van den. (2008). Towards closed cycles - New strategy steps inspired by the Cradle to Cradle approach. *PLEA 2008 – 25th Conference on Passive and Low Energy Architecture*. Dublin.
- Dobbelsteen, A. van den, Keefee, G., Tillie, N., & Roggema, R. (2012). Cities as Organisms. In R. Roggem (Ed.), *Swarming Landscapes: The Art of Designing For Climate Adaptation* (pp. 196–206). Dordrecht: Springer Science+Business Media.
- Erkman, S. (1998). *Vers une écologie industrielle*. (C. L. Mayer, Ed.). Paris.
- Gorgolewski, M., Komisar, J., & Nasr, J. (2011). *Carrot City: Creating Places for Urban Agriculture*. (The Monacelli Press, Ed.).
- Grospart, F. (2009). *Autonomie énergétique locale Sommaire*. Vendôme.
- IDDRI *Modes de vie et empreinte carbone* (2012).
- Jochem, E. (2004). Steps towards a sustainable development a white book for R & D energy-efficient technologies. Novatlantis.
- Jourdan, S., & Mirenowicz, J. (2011). L’agriculture regagne du terrain dans et autour des villes. *La Revue Durable*, 43.
- Lufkin, S., Rey, E., & Erkman, S. (2013). Quartiers symbiotiques: augmenter le potentiel d’autonomie énergétique à l’échelle locale. *Vers la ville symbiotique? Valoriser les ressources cachées*. Tracés.
- Lufkin, S., Rey, E., & Erkman, S. (2014). Quartiers symbiotiques. *Stratégies innovantes pour favoriser l’autonomie énergétique à l’échelle du quartier par l’intégration des enjeux relatifs aux bâtiments, aux infrastructures, à la mobilité et à l’alimentation*. CROSS, Final report. Lausanne.
- Newman, P. W. G. (1999). Sustainability and cities : extending the metabolism model. *Landscape and Urban Planning*, 44(February), 219–226.
- Previdoli, P. (2012). *Energiestrategie 2050*. In B. für E. BFE (Ed.), . Bundesamt für Energie BFE.
- Rey, E. (2006). Integration of energy issues into the design process of sustainable neighborhoods. *PLEA2006 - The 23rd Conference on Passive and Low Energy Architecture*. Geneva.
- Rey, E. (2011). *Concevoir des quartiers durables*. In OFEN / ARE (Ed.), *Quartiers durables. Défis et potentialités pour le développement urbain*. (OFEN / ARE., pp. 15–24). Bern.
- Rey, E., Lufkin, S., Renaud, P., & Perret, L. (2013). The influence of centrality on the global energy consumption in Swiss neighborhoods. *Energy and Buildings*, 60(0), 75–82.
- Thomas, M.-P. (2011). *En quête d’habitat : choix résidentiels et différenciation des modes de vie familiaux en Suisse*. EPFL.
- Tillie, N., Kürschner, J., Mantel, B., & Hackvoort, L. (2011). *The Amsterdam guide to energetic urban planning. Management and Innovation for a Sustainable Built Environment*. Amsterdam.
- Tillie, N., Van Den Dobbelsteen, A., Doepel, D., Joubert, M., De Jager, W., & Mayenburg, D. (2009). *Towards CO2 Neutral Urban Planning: Presenting the Rotterdam Energy Approach and Planning (REAP)*. *Journal of Green Building*, 4(3), 103–112.
- Wallbaum, H. (2012). *Mainstreaming energy and resource efficiency in the built environment – just a dream ?* In IED public lecture series (Ed.), . IED public lecture series.
- Zimmermann, M., Althaus, H.-J., & Haas, a. (2005). Benchmarks for sustainable construction. *Energy and Buildings*, 37(11), 1147–1157.