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Building resilient and sustainable: a need to decompartementalise the researches

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Abstract. For several years now, building resilient and building sustainable are two of the main challenges of urban planning in cities. Though, both challenges are usually treated separately at the operational scale, which may imply antagonisms or synergies. From a review of the literature, this paper highlights the fact that there is a need to "decompartmentalise" researches on resilience and energy efficiency to provide integrated professional tools for the design of future urban developments, especially in flood zones. In order to improve both resilience and energy efficiency, it appears that networks are key elements.

1 Introduction

According to a recent report of the European Environment Agency [1], building resilient and building sustainable are two of the main challenges of urban planning in Europe. For instance, in the French National Strategy for an ecological transition [2], one of the 9 axes is about the development of sustainable and resilient territories.

If, as pointed out by Redman [3], the two concepts are sometimes used interchangeably, they are not similar by definition. Sustainability is associated with the principles of efficiency, performance and even frugality. The concept of resilience is associated with adaptability, the ability to accept disturbances, recovery or transformative capacities. The responses in terms of urban design can therefore be potentially different.

According to Collier *et al.* [4], both concepts can be abstract or conflicting ideals and the lack of concrete examples or experience feedbacks do not ease operational actions. Moreover, both challenges are usually treated separately at the operational scale, which may imply antagonisms or synergies.

For these reasons we suggest in this paper that there is a need to "decompartmentalise" researches on resilience to flooding and urban energy management to provide integrated professional tools for the design of future urban developments.

1.1 Building resilient neighborhoods to flood

The high density of population and assets in cities make them extremely vulnerable to the effects of extreme weather events and climate change. Disasters in urban areas threaten the lives of an important number of people, take down critical infrastructure systems, conduct to high cost for damages and have had a high impact on interregional and global value chains.

The ever-increasing functions of cities are based on a growing complexity of urban technical networks (electricity, water supply, transport, internet, waste network, etc.), making the city more vulnerable to hazards and extreme weather events such as floods [5].

Recent disasters (hurricanes Katrina and Sandy in New Orleans and New York, Fukushima, hurricane Xynthia in French West coast, etc.) have shown that dysfunctions affecting cities could spread at larger scales of time and space than the hazard itself. In Greater Paris, 850000 inhabitants would be directly impacted – meaning located in a flooded zone - by a 100-year flood. However, around 1.5 million would be affected by major power-cuts and up to 5 million by drinking water cut-off [6]. In cities, most impacted people won't be located in flooded zone during future events because of cascading effects.

All the recent events such as hurricanes Katrina and Sandy took part in the development of the concept of urban resilience, which express the direct vulnerability of the city, but also its ability to operate in degraded mode, and return to an acceptable level of functioning after hazard [7-9].

However, today the sense of resilience and its ability to be operational in risk management fields remains unclear [9, 10]. Regarding urban design, several projects

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have been defined as "resilient" in the last years, especially regarding flood risk. In the development of Hafencity (Hamburg, Germany), a decision was made to implement infrastructures for pedestrians above the highest known flood level in case of emergency. In that area, buildings ground floors are also sealed up to that level and the bases of most buildings are used as parking garages [11]. In the neighbourdhood of Maasbommel (Netherland), amphibious houses have been built and can handle water level fluctuations of up to 5.5 meters. In Zuidplaspolder, houses are clustered on higher ground and are connected by raised infrastructures[1]. In the city of Rennes (France), an urban development district (Les Papeteries de Bretagne) proposes to adapt buildings to flood risk, by raising them. The buildings also play the role of a dike for the area behind, and infrastructures for pedestrians are built above the flood level[2].

In these “resilient” neighborhoods, the networks operability during crisis remains unclear. Among all technical networks, grids appear to be a key element as all other technical networks depends on it to function [12]. According to McNamara *et al.* [13], a resilient power system is “flexible, responds to challenges, enables quick recoveries, and is available when we need it most”. At the operational scale, this means that grids need to be decentralized in order to meet essential grid loads even during flooding. The traditional solution consists in using backup systems in the form of diesel generators during outages [13]. This solution is not an optimum as generators are idle most of the time and thus often fail to operate when needed. During Hurricane Sandy in New York, 50 to 60% of diesel backup systems were reported to have failed [14]. This kind of backup system is also very dependent to fuel availability during crisis, and is not economically viable. Regarding networks, it is important to identify new solutions in order to build resilient neighborhoods.

1.2 Building sustainable: focus on energy efficient objective

With abundant and cheap energy, urbanization of modern cities has not considered climate and energy constraints for their design and construction [15]. However these natural limits resurface today (tensions on fossil resources and climate change effects) and cities appear both as a principal cause of climate change (due to GHG emissions associated with urban areas) and as the spaces among the most threatened by the consequences of climate change (concentration of populations and activities) [16]. For IPCC, urban policies represent a double lever to control and reduce both the contribution of cities to climate change and their vulnerability to the effects of climate change [17]. Thus cities are, to varying degrees depending on the scales considered (district, downtown, metropolitan area ...), a key strategic lever for both mitigation and adaptation.

At the operational scale, many “green” neighborhoods have been built in the last years. In France for instance, 39 urban development projects have been labeled "EcoQuartier" since 2012 (7 in 2015, 19 in 2014 and 13 in 2013). They are a way to experiment new solutions such as: moving towards more sober and clean energy consumption, using decentralized energy sources and integrated production (combined heat and power system for instance) on consumer sites and the ability of urban designers and developers to easily integrate or not the energy challenges.

These new projects also question the relevant scale of reflection on the challenges of energy. Tardieu *et al.* [18] show that appropriate solutions at the building scale can be detrimental to the neighborhood scale. In the studied case, the implementation of a heat network could be jeopardized if it does not cover all the heat needs of the district. With a growing renewable energy production at the scale of buildings and neighborhoods, developers will be required to have a reflection from the upstream phases of projects to ensure consistency. Thus, many projects illustrate the possible innovations in energy resource.

In the neighborhood of Noorderhoek (Netherlands), a utility building located in the middle of 200 houses is used to treat sewage locally. The treatment – from an anaerobic digestion process – enables to produce biogas for 12% of the neighborhood. The hot greywater from home enable to heat the houses too. This achieves an additional 10% reduction in total energy use[3]. In the neighbourdhood of Hammarby Sjöstad (Sweden), the main source of heating is district heating: 34% of the heat comes from purified waste water. When the heat has been extracted from the warm, purified waste water, the remaining cold water can also be used for district cooling, for instance in the cold storage of grocery stores.[4]

In the eco-districts of Roquebrune Cap-Martin (Alpes-Maritimes, France) and Centre Sainte-Geneviève – Nanterre (Hauts-de-Seine, France), heating networks have been set up and are powered by including energy recovered from the waste water. Then, the treated water from the new municipal wastewater treatment plant in the first case and wastewater flowing into the sewerage network in the second become sources of energy.

Seeing these examples, we can wonder how these “green” neighborhoods would behave during a disaster. Would these technological “green” solutions be an asset for the resilience of the area, during the crisis, for the recovering?

[1] http://www.urbangreenbluegrids.com/projects/hammarby-sjostad-stockholm-sweden/
[2] http://www.seinegrandslacs.fr/docs/Vuln%C3%A9rabilit%C3%A9/PREVIRISQ/Atelier%209/PREVIRISQ%202010_Atelier%209_Jean-Yves%20Barrier.pdf
[3] www.waterschoon.nl
[4] http://www.urbangreenbluegrids.com/projects/hammarby-sjostad-stockholm-sweden/

2 Building resilient and sustainable: differences, gaps and clashes

At the operational scale, resilience and sustainability are related to different agendas, regulations, stakeholders and measures, which may lead to several issues.

According to Toubin *et al.* [19], speeches related to resilience have a performative dimension, such as risk management before it and as injunctions to sustainable development now. Thus we can observe the construction of urban land shaped by both risk management and sustainable development goals. The stakeholders of the city use these issues to legitimize development projects, which often have strong gaps on one aspect or another. According to the authors, we can thus question the operational range of these displays and especially the actual contribution to the sustainability and resilience of these territories [19].

Most of methods and tools developed to face natural risks, climate change and energy transition challenge in the city have been designed separately. Nowadays, many sustainable development tools such as sustainability assessment frameworks (SAFs) are used to guide practitioners to design sustainable urban infrastructures. By analyzing several existing SAFs, Matthews *et al.* [20] revealed that hazard resistance and resilience are not strongly enough integrated into sustainable design. This gap could lead to the design of structures that are vulnerable to extreme events [20].

International and national regulations regarding risks, energy efficiency and adaptation to climate change - energy efficiency directive, floods directive, water framework directive etc. - can sometimes appear as constraints for urban planners but are also a way to offer more efficient, more pleasant, safer cities. However the multiplications of regulations and injunctions question the possible synergies and shared objectives or, conversely, the contradictions during their application. In United Kingdom, Lizarralde *et al.* [21] have for instance examined the tensions and complexities that appear between the “sustainability” and “resilience” agendas regarding the built environment. The study shows that different representations of the sustainable and resilience paradigms cause important tensions between the agendas in the built environment. For instance, regarding system performances, sustainability promotes the capacity to function with the minimum use of resources, while resilience promotes redundancies to avoid system breakdown.

All these elements show that there is an important need, at a practical level, for a better comprehension of the consequences of implementing and enforcing both resilience and sustainability at the same time [21], and to cross the objectives and analyze all the impacts of a choice. Indeed, if both agendas may lead to tensions and antagonistic solutions, they may also bring opportunities at the operational level.

3 Opportunities through the scope of urban networks

3.1 The use of renewable energy during crisis

Some visionary papers have highlighted the role of renewable energies as emergency power sources during disasters [22, 23]. Technological progresses regarding battery storage systems improved the reliability of such energies (eg. solar), which can help during disasters [24]. However, experience feedbacks are still needed to observe how renewable energies operate during disasters. Many green energy systems failed when Hurricane Sandy hit the east coast of the USA in 2012. For instance, household solar systems stopped to operate because they are linked to the main grid and they automatically shut down when the main grid fails. This is required by regulatory code for security reasons [25].

According to Miller [26], distributed energy systems are a solution to provide essential services during disasters while centralized systems are disrupted.

3.2 Distributed energy resource (DER): a synergetic solution ?

Unlike centralized system such as national grids, DER systems are decentralized and located close to the load they serve. DER are then more flexibles than centralized systems. During Hurricane Sandy, DER allowed some critical infrastructures, such as hospitals, wastewater treatment plants and universities, to remain operational while the main grid was down. According to Giotitsas *et al.* [27], the peer-to-peer approach to energy production of DER offers greater resilience than centralized systems “since the collapse of one of its components does not influence the entire network”. DER co-benefits are also numerous: lower energy costs, cleaner environment through the possible use of renewable energy, and higher efficiency.

The concept of microgrids has been defined by Lasseter [28] and Marnay *et al.* [29] as a “cluster of small sources, storage systems, and loads, which presents itself to the main grid as a single, flexible and controllable entity” [30]. In other words, microgrids are local grids that can be disconnected – islanded - from the main grid and thus operate autonomously. When the main grid is down - due to a flood for instance - a microgrid can be safely isolated and continue to deliver power localy [30]. Microgrids are thus useful both in normal operation and during emergency situations, unlike traditional backup systems such as diesel generators. By providing an alternative when the main grid is down, microgrids add redundancy, which is a crutial element of resilience for the networks.

Many sources of energy can be used to generate electricity within a microgrid, and among them renewable energies. Microgrid can also be coupled with CHP systems in order to produce heat beside electricity. According to McNamara *et al.* [13], microgrids are thus successful at achieving the two objectives of resilience and emission reductions.

Some microgrids are planned to be built in the next few years in order to increase the resilience of vulnerable urban neighborhoods. One of these projects will be located in the city of Hoboken (New Jersey) which is particularly exposed to flooding. During Hurricane Sandy, almost the entire city was underwater and without power for two weeks. The future microgrid is designed to provide power for 55 buildings (police and fire stations, accommodations, essential shops etc.) during disasters. The microgrid will be powered by natural gas generators and renewable energy at start, but is designed to use 100% of renewable energy in the future[5]. New York City is also planning to implement microgrids to improve its resilience to coastal flooding. One project is for instance planned in the Rockaways on Long Island[6]. Several other microgrids are planned in USA (Washington DC, Maryland etc.). In Europe, an interesting project should be implemented in Hackbridge (United Kingdom). Located in a flood zone, new buildings will be powered by renewable energy sources: solar panels, biomass, heat pumps and a mini-hydro production of less than 100 kW. These facilities are intended to operate during a flood, the types of renewable energy having been selected based on their compatibility with the risk of flooding [31].

4 Discussion

From an operational perspective, building both resilient and sustainable implies to resolve many challenges but does not seem impossible. According to some authors, one of the essential prerequisites is to take into account urban networks, and especially electricity. Kinn and Abbott [12] highlighted the fact that the role of electricity is underrepresented in the resilience and disaster management literature. According to the authors, this key network should be taken into account more significantly into resilience research. However, other research avenues need to be conducted in order to attain both goals.

Local distributed energy resources such as microgrids seem to be viable solutions, but thinking about their scale of implementation is crucial. Moreover, microgrids do not have to replace the main grids which remain essential. Microgrids should only offer an alternative in case of disasters.

We can wonder if the use of renewable energies and the development of microgrids are cost-effective. For several years now, economic conditions seem more and more favorable for the use of renewable energy. For instance, the average cost of wind power and solar photovoltaic in USA has declined by more than 60 % over the past 5 years [13]. Mullendore *et al.* [24] demonstrated that solar panels coupled with storage systems can "reduce costs and increase power resiliency in multifamily affordable housing". Regarding microgrids, Stadler *et al.* [30] indicate, from a literature review, that significant economic return can be attained by their development. The authors thus conclude that there is an important economic potential in developing microgrids.

Adapting the cities by implementing microgrids and using renewable energies seems to be a significant challenge. Indeed, the retrofit of existing network in dense cities is a complex, long and expensive process. However, it is also essential to think about the future reconstruction of the cities before major disasters occur. If not, cities will be rebuilt as before which is not resilient. For this reason, researches on the future development of microgrids and their impact on resilience and sustainability need to be conducted.

Many regulatory and financial challenges need to be resolved regarding the future implementation of microgrids to improve urban resilience. For instance, many microgrids are based on public buildings (schools, hospitals etc.), but some private buildings are also essential (supermarkets, gas stations, housing etc.) for the functioning of a city during disasters. Thus, public-private partnerships or communities would need to be built to implement efficient microgrids in cities. Moreover, in France, the decentralization of energy production is opposed to a strong tradition of centralization. Poupeau [32] points out the three elements involved in this "resistance to change": 1 / the state is very present in the energy planning of the means of production; 2 / The neoliberal paradigm of competition (freedom for consumers to choose their energy) perpetuates the French tradition of Jacobinism; 3 / rural areas greatly structured territorial governance of energy with the laudable aim to not differentiate the treatment given to cities compared to rural municipalities. New energy solutions therefore need to find their place in, sometimes, an unfavorable context. The issues of sustainability and now resilience could facilitate their implementation.

If microgrids may represent a potential renewable solution to avoid power outage during flooding, many questions remain regarding other essential networks. Ecological sewage systems, water sensitive water design or geotherrmy are solutions that may improve urban resilience. However, their role during disasters still needs to be further investigated. According to Falco and Randolf [33], it is possible to apply the concept of microgrid to improve the resilience of water infrastructure through the concept of water microgrids. For McPhearson *et al.* [34], urban ecosystem services have also an important role in building resilience and sustainability in urban systems.

If this paper focuses mainly on flood risk, there is a need to develop multi risk approaches. The technical

[5] http://www.govtech.com/fs/Flood-Prone-East-Coast-City-Plans-Microgrid-to-Keep-Power-on-for-the Vulnerable.html
[6] http://www.climatecentral.org/news/sandy-motivates-ny-to-explore-microgrids-18253

solutions developed to strengthen the resilience of a territory are indeed often considered independently depending on the risks (Resilient solutions for flood; solutions for heatwaves …). Technical solutions are applied independently for flood risk [35], heatwave [36], drought [37] etc. However territories are subject to multiple risks and some technical solutions implemented to tackle one issue may strengthen or weaken the resilience of a territory regarding other hazards.

5 Conclusion

Based from a review of the literature, this paper demonstrates there is a need to decompartmentalise researches on resilience and energy efficiency. This would help contractors in the selection of technical solutions for the energy performance and resilience of urban development projects in areas likely to be impacted - directly or indirectly - by flood or other hazards.

Even if both resilience and energy efficiency have different goals or agendas, there are some opportunities at the operational scale. It appears that networks are key elements to improve both resilience and energy efficiency.

Litterature show that distributed energy resource systems are interesting solutions, as they are successful at achieving the two objectives of resilience and energy efficiency. More experience feedbacks are needed on other possible synergetic solutions (geothermal energy, ecological sewage systems etc.).

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