From the 16th to the 21st century: upgrading Traditional Knowledge to approach Net Zero goals in existing neighborhood upgrades (ZERH-NU)

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ABSTRACT

Ancient buildings are examples of resilience and versatility, and their capability to persist throughout the centuries should be appreciated as a symbol of sustainability. However, the public perceives existing buildings as uncomfortable and unhealthy energy hogs, which they can easily become without proper use, “rehabilitation” or maintenance. This paper explores the “traditional knowledge” embedded in construction practices to achieve Net Zero goals, a new name for a centuries-old energy security and comfort-aimed sustainable practices. The deep assessment and upgrade options for Montarroio, a residential building within Coimbra’s UNESCO Heritage area, are briefed extending the IEA EBC Annex 56 on “Cost-Effective Energy and Carbon Emission Optimization in Building Renovation” methodology. Neighborhood scale interventions are demonstrated as awarded processes to streamline and optimize cost-effective measurable results. “Zero Energy Ready Home”- Neighborhood Upgrades (ZERH_NU) are proposed as feasible adaptations to include existing (contemporary) residential neighborhoods in a step change for energy efficiency advocates: from “pushers” of technology to catalysts of collective change.

Introduction

Harnessing the energy savings potential of existing buildings is a milestone to meet the targets for a Low Carbon Economy in 2050 (EC 2011) as all buildings will have to reduce their energy consumption, and/or transition towards low carbon energy sources, while guaranteeing better comfort and indoor environmental quality (IEQ). Many policy efforts focus on new buildings, even though (1) the vast majority of the 2050 building stock already exists (UNEP 2007; Marnay et al. 2008), and (2) new buildings are a limited market: in Europe new housing stock only represents 1-2% per year (UNEP 2007), and a decline is forecasted due to economic and demographic issues. This paper agrees that “the greenest building” is the one that is already built (PGL 2011), while acknowledging that incomplete assessments are sometimes used to justify demolition, or to layer fashionable “innovations”.

Starting with the premise that each building is a sign of the time it was built, this paper draws on historical accounts to broaden the readers´ imagination on how issues of energy and comfort were solved in a time before ours, and to invite them to identify feasible solutions aligned with their specific habits and preferences. The paper begins by providing brief background of the “Traditional Knowledge” (UNESCO 2000; Brito et al. 2014b) embedded in medieval European urban construction. This provides a basis for suggesting that medieval users were able to enjoy some level of comfort in their homes, and that we may still learn from them. Next, it draws on a deep assessment of an ancient building to demonstrate that new tools—photogrametry, thermography, IEQ environmental, dynamic simulation and others—can bring new views into perspective. Data and depictions of data—information—are then used to read the underlying dynamics optimized through centuries of construction and use, from these innovative reinterpretations can be suggested, evaluated and brought into today´s use.

Assuming the need to scale up Energy Efficiency (Bullier and Milin 2013) in the existing residential sector, an awarded neighborhood scale Energy Service strategy for Historic Areas, is revisited, and an exploratory strategy proposed to existing residential neighborhoods.

The authors argue that Information and Communication Technologies (ICT) can provide new insights about existing buildings and neighborhoods, and new ways to engage residential building owners into collective actions to protect both the environment and their property value.

Background

Montarroio is a street within the UNESCO "University of Coimbra –Alta and Sofia" and "Jardim da Manga" National Monument protection areas (UNESCO 2013). The case study lower levels date back to 14th century, while the upwards extension denotes stone-embellished windows and a chimney, 16th century exterior signs of comfort (Trindade 2002). As in over 800 ancient buildings nearby (and millions in Europe), stacked masonry walls provide peripheral support to wooden floor levels and roof structures, covered by ceramic tiles.

Thick walls sliming towards the upper levels define growing internal areas: 13,7m² in a semi-buried level with separate entrance with severe humidity issues, commonly used to shelter animals. Only 36m² are habitable, 15,3m² on the intermediate level and 20,6m² on the top level. Wood doors and interior shutters prevail, with 19th century simple glazing sash windows that assure high infiltration from lack of maintenance.

Figure 1: Panorama view of Montarroio street and the Montarroio case study, highlighted. *Source:* Brito, 2010.

The 16th century context in Europe

A small excursion into the past with "A History of Private Life" (Duby 1988) helps to describe how users and buildings teamed to guarantee comfort in the 14th-16th centuries. These post "Black Plague" times were characterized by "the rise in the overall standard of living that followed the period of depopulation initiated by the pandemic" (Duby 1988, x-xi). The effects of the increasing use of money on the notions of property and collective created "a gradual transition from a gregarious to a more individualistic existence, which lead to greater introspection; within the privacy of the house there developed an ever more intimate preserve, an inner privacy of the self" (idem xii).

This individualistic trend in housing was contested long before modern communes, co-housing, and new urbanism developed. In 1314 the Venetian Franciscan Fra Paolino advised: *"Fagli mestiere a vivere con molti* (Make it your business to live with many others). (…) To live in society was to participate, according to Paolino, in three progressively more exclusive communities: the overarching political community (city, kingdom, or other entity); the neighborhood (*vicinato*), and the household. His view, widely shared, was that distinct groups coexisted within the public sphere, the city or the kingdom: “these groups enjoyed sufficient autonomy to be considered ‘private’. Though centered in the house (...) private life was not confined within its walls. Through the network of neighbors the family thrust its antennae into the wider community—the city or canton.” (idem,157). This paper emphasizes the continued relevance of neighborhoods, contemporarily demonstrated by their impact on property prices.

On the possibility of Net Zero houses and neighborhoods in the 16th century

Paolino’s description of who lived in a house is useful for energy calculation purposes: “inhabitants included a husband, a wife, their children, and no one else save a female to wait on them” (Duby 1988, 157). Although generations cohabited, this information together with medieval tax statistics suggest that households were generally composed of a family of four. Considering the similarity of Mediterranean climate, urban construction practices –not in wood to reduce fire risk– and the surprising circulation of people and ideas throughout Europe around 16^{th} century, it is fair to assume Fra Paolino’s depictions for Venice were valid for Montarroio. Much as photovoltaic panels or grand porticos signal affluence today, in Paolino’s time the stone embelished windows and chimneys signified a medieval family’s economic capacity to provide light and heat. How did these ancient buildings ‘perform’ by modern standards?

Acknowledging that ancient buildings were designed for continuous use, as still observed in many rural areas of Portugal and Europe, this translates into natural convection heat flows from basement—animals as heat engines—and indoor continuous heat sources from users, fire or hot ashes in between meals. Furthermore, constant human presence favors adequate use of heat gains from the sun, heat losses control at night and ongoing, generational, fine-tuning. Thermal comfort (INNOVA 1997) scarce energy needs in wood, carbon neutral, can be estimated:

- Recent tests in Montarroio depict an hourly consumption between 0. 6 and 1.1 KWh in the coldest month (February) to keep interior air temperatures between 18 and 20ºC, ignoring solar heat gains and adaptive comfort strategies (appropriate clothing). This electric consumption surpasses local neighborhood reported values (see Brito et al. 2015).
- A family of four, and a servant, with metabolic rates ranging from 83W each sleeping to 180W while performing domestic work produce from 360W to 600W interior heat;
- Cooking was done inside in the winter, generating heat gains, and biomass was, and still is, a current source for heating. Having in mind that dried wood provides about 4.1 KWh/kg, not many logs where necessary to secure today’s levels of comfort in the winter. No cooling is necessary if the window shutters are properly used in the summer.

Although neighborhoods are composed of houses, communities are more than just sticks and bricks. They include and are formed by people and social relationships, both within and across houses. This was as true in medieval times as it is today.

One example are the “communal ovens” used to bake bread, a solution to share both resources and good will, irrespective of individual wealth. Participating in the neighborhood bread baking process was, and still is, a social process maintained in some areas, and recently imported as a social tool by others (PPS, 2016).

(Backstage) Methodology

This paper argues that deep assessments towards neighborhood upgrades can be the new "communal kitchen" in which community climate change mitigation actions are formed. As such, it relies more on the process, which can be adapted and optimized, than on the results, which will vary for each analyzed building and neighborhood. The first part of this section focuses on finding Net Zero by describing what "deep assessment" is and can provide. The description is based the Montarroio house, and it includes the role of comparative parametric analysis and visualization, showing that multiple assessment approaches are necessary to select an appropriate net zero solution. The second part considers how to make the most appropriate solution affordable by (1) considering multiple non-energy benefits and (2) engaging multiple properties and stakeholders to share installation and maintenance costs.

Finding Net Zero: Deep Assessment Before Deep Renovation

Assessment is defined as the action to "Evaluate or estimate the nature, ability, or quality of". In the Montarroio case study, the deep assessment targeted on performance-based goals of "nearly Zero Energy Building (nZEB) and/or Net Zero, focusing in the building / user's team, and their relation with the neighborhood and local climate. This process goes beyond the specific building, fostering intersections with other areas of knowledge to detect and communicate ways to harness their undervalued potential. Brito and Gameiro da Silva (2014a) previously illustrated this process with typical times and costs retrieved from the Montarroio case study. Technologies like photogrammetry and drone flights were used—and attracted the neighbors curiosity—, digital reconstructions processed into 3D faces, Building Information Models (BIM) used to develop design alternatives, and models exported for dynamic simulation (see Figure 2).

Figure 2: Drone flight images (left), Autodesk Revit 2012 modelexported using gbXML to dynamic simulation software like Ecotect and OpenStudio/EnergyPlus (middle) and 3D printed model (right). *Source:* Brito 2014.

Online monitoring of indoor and outdoor parameters—temperatures, relative humidity and CO_2—composed a detailed picture of the building behavior, fine-tuned dynamic simulation models and confirmed the potential of thermal inertia for energy savings if adequately used. Detail on the process is available in Brito and Gameiro da Silva (2014a) and Brito et al. (2014b).

Visualization: from data to information, usable by others. "Tailor-made" depictions of invisible forces like heat, energy, and global warming potential (GWP) can describe complex elements of expert knowledge graphically, facilitating effective communication between stakeholders. A simple example is the use of infrared thermography, an imaging technique that visualizes variations in temperature, to translate the superficial effect of walls' thermal inertia.

Figure 3 (left) upper row depicts exterior thermograpic images of the same window at three periods, and in the lower line the corresponding indoor images: exterior winter daily temperature variations have reduced influence on indoor walls faces, even without acclimation. With ICT this visual representation can go beyond the visible layers: Figure 3 (right) illustrates inside-wall temperature measurements digitally associated to the 3D model: the history of slow temperature changes and inertia thermal flows can be graphically browsed moving a time slider.

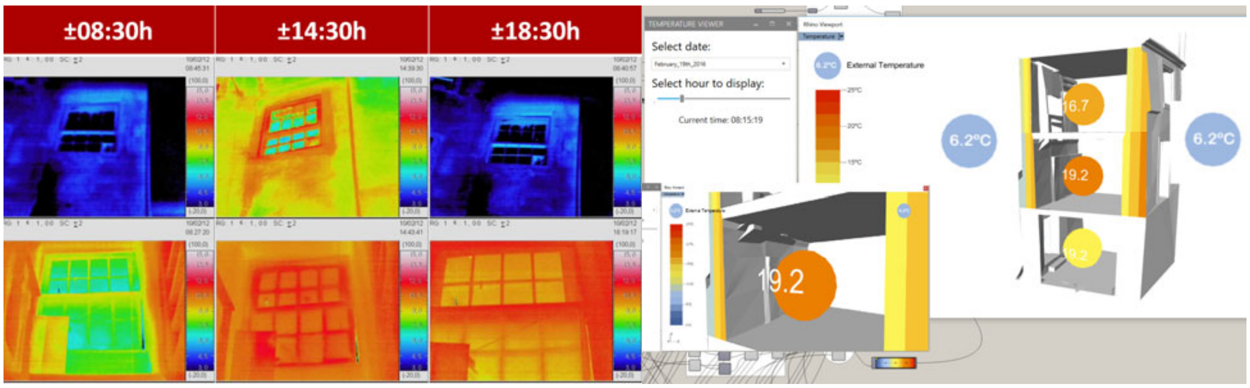

Figure 3: A group of thermographic calibrated (3 to 15ºC) images of the same window (left) and a Rhinoceros / Grasshopper / Human UI visual readout of data (right) (special thanks to student E. Aguero for the add-on reference)

Tailor-made depictions make representations of the reality attractive and understandable by others beyond specific areas of knowledge. Limitations like the difficulty to read plans and cuts, to anticipate cost scenarios and to include holistic complexity find in these models the multidisciplinary convergence needed for applied interdisciplinary studies. But it opens up beyond what is represented: the bi-directionality of ICT allows for virtual feed-back, trial and error approaches, facilitated post-occupancy evaluation and new "virtualities": from a smart-energy connection to a warning on a heat wave with a "to do" checklist for a resilient response.

Can this ancient relationship between the user and the building be transposed to typical modern usage patterns, where users leave in the morning to come back only at night? In the Montarroio case study, solar thermal panels can be used to "fill in" for their absence. Brites et al. (2013) demonstrate in "Solar cooling as Optimization of Conventional Solar thermal Systems for Existing Buildings' Upgrade Interventions" that solar thermal panels can guarantee the majority of heating needs in winter, and that (summer) overheating can be solved by Brites' investigation on small scale adsorption unit: the storage tanks, hot and cold water, transform solar energy into delayed-use energy to be managed according to the season. In the rare times when the sun is not enough to heat the needed water, a wood stove with a water-based heat recovery system can replenish the heat in the tank and house, and roast a caloric Mediterranean winter meal.

Visualization tools empower owners and users with a better understanding of their house's physical behavior, but have limited effect on their renovation decisions. The Montarroio Shining Example (Brito, 2016) adapted the methodology jointly developed within IEA Annex 56 "Cost Effective Energy and Carbon Emission Optimization in Building Renovation (Morck et al., 2016) to evaluate five options.

Planning by comparing alternatives. BIM and its “chronological dimension” streamlined the depiction of five intervention (Figure 4) scenarios superposed on the 3D model: each column represents a cut from the same position, now (Opt.0) and in four virtual futures (Opt.1 to 4).

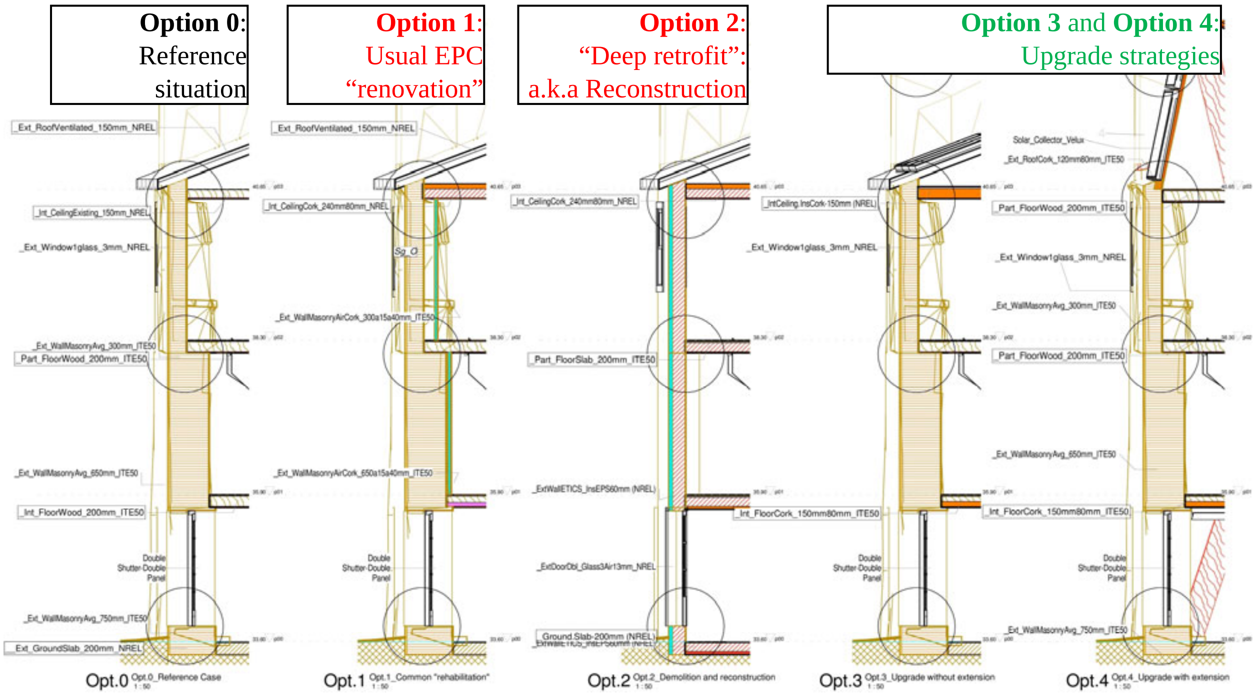

Figure 4: Montarroio studied intervention alternatives, detailed information on each option available in (Brito, 2016)

Fig. 5 depicts indicators like the Initial Investment Costs (IIC) per square meter, the value paid up front, the Life Cycle Costs (LCC)—comprising IIC, equipment maintenance/replacement each 15 years and energy costs in 30 years, all divided by 30 as if paid annually—and environmental impacts depicted through Global Warming Potential (GWP).

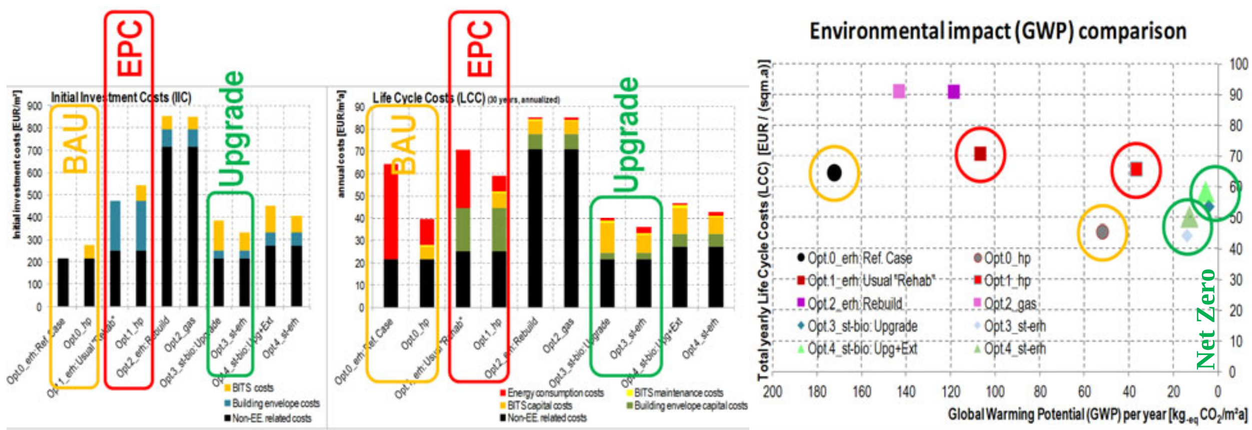

Figure 5: Option comparison of Initial Investment Costs (left), annualized Life Cycle Costs in 30 years (middle) and Global Warming Potential analysis using (EcoBat, 2014) (right). A 6 page leaflet is available in (Brito, 2016).

The Life Cycle Impact Assessment (LCIA) evaluation expressed in GWP parameters (Fig. 5, right) demonstrates that, for this climate and building type, Option 0_hp—heat pump heating / DHW approach, grey circle—has smaller long term impact on the environment, and owners' pockets, than Option 1_erh—electric resistance heating, dark red square— or Option 2_erh—electric resistance heating, light magenta square. And better results are demonstrated.

Affordable Net Zero: valuing multiple benefits and collective action. In Option 4_st-bio—solar thermal heating / DHW approach with biomass backup and solar adsorption cooler, light green triangle— insulation is placed only in the accessible cavities, the ceiling and floor over the basement, easy to install. A reinforced structure for a vertical extension provides additional floor area, and value added to the property by improving comfort, increasing floor area in a prime location, and enhancing safety: in a seismic event damage would occur, but collapse and complete property loss would be avoided.[1] **A question remains: is Net Zero a good investment** within this UNESCO Historic Area, where neighboring buildings cannot reach basic conditions?

Moreover, the golden rule for keeping an ancient building in good working condition is preventive maintenance, and so is true for new and sophisticated renewable energy systems. Many investments in energy efficiency result in lower operational costs, but annual maintenance can reach around 10% of the initial investment per year in individual installations: considering similar total annual prices, is it worth to invest on a new technology, with unanticipated risks?

Fra Paolino's advice is useful: "*Fagli mestiere a vivere con molti* (Make it your business to live with many others). Group / collective neighborhood purchases reduce initial contextual, investment, installation, optimization and maintenance costs, and scale attracts competition. But how many neighborhoods can make an informed decision without expert help? The next section considers how utilities, policy makers and companies can make a difference by establishing basic guidelines, and how ESCOs have the opportunity to make energy efficiency available for all.

"Scaling up" Energy Efficiency in neighborhoods

Divide et impera, the Roman strategy to divide and conquer its opponents, still prevails in the majority of ongoing energy efficiency strategies. By dividing energy consumption into sectors (Industrial, Services, Residential, Transportation), by pooling similar clients and by focusing on the easy and low hanging fruit of each sector, energy efficiency advocates may actually lose the whole by focusing only on some of its parts. As economist Herman Daly has noted: "Future progress simply must be made in terms of the things that really count rather than the things that are merely countable (Daly 1996, p. 354). Similarly, Janda (2014) and Moezzi and Janda (2014) have argued that "social potential"—which draws attention to things that groups of people actually do and are interested in—may be a more useful objective for energy efficiency advocates than technical potential, which largely focuses on people as individual rational economic actors. The deeply historic approach of the current paper suggests that both individual and group objectives—like preserving property value embedded in neighborhoods and engaging in communal activities—are intertwined with maximizing energy efficiency potential.

The authors further argue that although most technologies already exist, "bottom-up" and "top-down" processes fail to properly address all stakeholders in their specific motivations and

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[1] More detail in forthcoming publication: "A roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities", https://bookshop.europa.eu

needs. The next section addresses a "middle-out" approach (Janda and Parag 2013) that builds on the deep assessment process of Montarroio to act towards neighborhood scale energy efficacy.

"Common Efficacy"[2]: an European strategy for (Historic) neighborhoods energy efficiency

An "eceee Summer Study 2015" paper entitled "Residential buildings as extended territory for ESCOs" (Brito, Fonseca et al. 2015) identified in neighborhoods and in the natural urban stakeholders –residents, local communities, policy actors, universities, energy service companies (ESCOs) and owners– a set of "win-win" opportunities: collective responses to reduce costs, optimize efficiency, promote inclusive neighborhoods and better quality of life.

By engaging local stakeholders in neighborhood scale interventions, costs (awareness raising, assessment, depiction, design proposal, planning, funding, procurement, installation, maintenance and optimization) are reduced. By implementing measures progressively, a small team of experts suffices, and learning curves evolve. Community-level enrolment overcomes the fact that only informed, technically able and financially capable inhabitants –a small number in such places– can act consciously towards emissions reduction, and access available funding.

In Coimbra's constrained UNESCO area, the Common Efficacy strategy builds on the deep assessment findings to propose low temperature district heating based on renewable energy. The local owners' limited investment capacity and rent increase restrictions justifies the city hall investment on the infrastructure, a local association manages contracting and ESCOs provide equipments, operation and maintenance through a "flat-rate" hot water service. To entice residents (and non-resident owners) connection, EE measures are offered and progressively implemented at neighborhood scale, making use of existing funding mechanisms to optimize and maintain throughout the contract longevity. The "win-win" advantages are relevant:

- Residents gain better comfort for a lower monthly cost (and energy poverty reduction);
- Local communities' gain a percentage of the revenue to intermediate with ESCOs, identify/solve small issues and maintenance tasks and to continue their social goals;
- Policy actors find partners to make better use of the available investment funding, have more attractive areas and results to show, locally and internationally;
- Education stakeholders gain access to "hands-on" real world scenarios practice and optimization, attracting the future generations and associating some to the related tasks;
- ESCOs make use of their knowledge to contract better systems for lower prices, support investment with existing financing opportunities and make a profit from monthly fees;
- Owners gain increased global property value with limited investment.

And a "plan B" exists: in the event of a stall between stakeholders, the off-peak wind renewable energy production excess, of low value, can be stored in individual heat storage units: a contact by a wind energy / ESCO Spanish group validates the potential of this alternative.

Investigation proceeds on less expensive processes to collect data, smarter ways to retrieve information, strategies to make information more attractive and Integrated Project Delivery (AIA, 2015) strategies to facilitate neighborhood scale interventions in existing areas.

[2] "Common Efficacy", was awarded the first prize in the "Urban Services and the Connected City" category of VINCI Innovation Awards. More information in (Brito et al. 2015), video at www.uc.pt/en/efs/destaques/2016/vinci.

Towards ZERH-NU: inclusive "Neighborhood Upgrades" in the USA

This topic builds on the "Common Efficacy" strategy and on the "Community-Wide Zero Energy Ready Home Standard" report (Herk and Beggs 2016) to argue that conditions, advantages and middle-actors exist to apply collective strategies in existing USA neighborhoods.

"Community-Wide" ZERO strategies propose new neighborhood construction with high levels of comfort and reduced implementation costs through scale and holistic approaches; and so can existing neighborhoods with adapted methodologies and solutions. Like in the "Common Efficacy" proposal, multiple stakeholders must play a role—from basic guidelines definition by Policy makers to knowledge transfer from the Universities and guidance from Utilities for a better match with the network, all the way to (future) local communities' engagement.

Net Zero buildings as defined by Torcellini et al. (2006) challenge the dogma that most of the GWP impacts occur during the use phase. Nevertheless the **Net Zero visibility remains on new developments**, and differentiation arguments emphasize aspects that existing buildings were never designed for, and have trouble to deliver: air tightening existing envelopes can have unbearable costs, and little added property value, often suggesting demolition and reconstruction.

"Zero Value" is intrinsically casted to existing buildings by some Net Zero approaches, forgetting that buildings reflect the technologies and expectations of specific time and place; and that the "reuse of buildings with an average level of energy performance consistently offers immediate climate-change impact reductions" (PGL, 2011). In fact GWP impacts of existing buildings are only those of operation and maintenance, with limited demolition materials transport and deposition, and small new materials production, transport and installation impacts. A simple example is the energy switch of an electricity-based 1980´s building to Renewable Energy sources, which can take it towards negligible impacts with minimum costs.

This "Zero Value" risk, or the abrupt loss of value that existing residential buildings and communities can suffer from the comparison with their Net Zero counterparts, may be useful to unite most of the owners, and the reader, into alternative approaches to value their property, as these are **lifetime investments that families and communities will try to protect**. Communities already develop joint actions that range from minimum garden-keeping to complex shared services, but other stakes rule the game: neighborhoods are placeholders for property value, collective pride, sense of belonging and sharing practices, just like Fra Paolino states.

Affordable ZERH-Neighborhood Upgrades can be triggered by "middle-actors" (Janda and Parag 2013) able to empower neighbors on the advantages of ZERH-NU strategies, and build from each case: scale, optimization and practice do result in speed, quality and lower costs.

Although starting costs exist, how much is worth to inform a neighborhood on the best actions to perform, and to **accelerate/influence building upgrades with detailed information**? Acknowledging that there is funding available for investigation, enhancing resilience and fighting fuel poverty in existing buildings, the initial costs will probably be covered by policy stakeholders to guarantee that the chosen solutions go in line with collective goals.

As demonstrated in the Montarroio case study (Brito and Gameiro da Silva 2014) it is unreal, physically and economically, to expect all buildings to be equipped with complex sensing/actuation technologies to help owners spend less and make informed choices, but the effect of demonstration and sharing is know. From here, much can be done, collectively. A few participants will catch the top of the ICT wave, and feel happy to share data with neighbors: can it be as fun to evolve from "Pimp My Ride"[3] to "Pimp My Neighborhood"[4]?

The advantages of the community scale go beyond those described in the "Common Efficacy" topic. Instead of acting alone, with standardized solutions that rarely match to non-standard situations, neighbours and "middle-outers" can draw comprehensive intervention plans towards specific targets, and evaluate them through benchmarking: the pride of showing results.

A well planned 20% carbon emission reduction in many existing neighborhoods has more impact and lower cost than all the new "Community Wide ZERO" that might be built at the current rate until 2030; may easily be upgraded to achieve ambitious goals (50%, 100%); may include cooperation with utilities for peak shaving strategies, integrated smart grids and IOT.

ZERH-NU (Zero Energy Ready Home-Neighborhoods Upgrade) can be active partners towards cost-effective Energy Efficiency and Renewable Energy measurable results.

Conclusion, or "We´re gonna be Zero-New soon" (a.k.a. ZERH-NU): a start?

This paper started with an exploratory trip back to the 14-16th centuries to consider how medieval buildings and their inhabitants found adequate levels of comfort with the technologies and energy sources of that time. Comfort resulted from a careful interplay between building construction and social practices learned/passed forward across generations. This paper proposes deep assessments as triggers for new reinterpretations towards Net Zero; that such logic holds true to recent buildings; and that cost-effective EE interventions must privilege optimization—instead of demolition and reconstruction, a strategy that casts "Zero Value" to existing assets.

In fact, property value preservation may be a driver towards EE upgrades. By using technology, new views on existing relations are possible. Building Information Models (BIM), Building Energy Models (BEM) and parametric "represent-actions" are bi-directional tools to organize and visualize information, but also to communicate, influence or complement users' choices, digitally replicating the (former immediate) sensible feed-back of our actions.

By engaging middle-actors (Janda and Parag 2013) that already exist in the market, neighborhood deep assessments can be scaled to relatively recent buildings from which the available paper blueprints rarely matches with what was built, and changed by man or time. Research centers, universities, training agents, energy service companies, policy actors, local communities and many more stakeholders can act to achieve scale and measurable goals.

Neighborhood scale approaches have relevant advantages: some users will have all the gears, some will have a particular knowledge, some will have absolutely no motivation to budge, many more will favor decision making by the barbecue, but all will share common motivations: to safeguard the value of their property and project a good image of their neighborhood.

"*Fagli mestiere a vivere con molti* (Make it your business to live with many others)", said Fra Paolino in 1314, in a clear advice to enjoy your neighbors diversity as a channel towards a better engagement with the city and the world, to scale collective potential, to show results.

"**Make it your Net Zero business to act with many others**", the ZERH-NU proposal suggests now, in the expectation that others will see the results, 702 years from now.

[3] https://en.wikipedia.org/wiki/Pimp_My_Ride

[4] Although the aesthetical results might be arguable, "car tuning" exemplifies the investment of time, knowledge and money that motivated people can put into enhancing their vehicles: how far can they go with their property?

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