Energy Sufficiency in (strongly intertwined) Building and City Design. Examples for temperate and mediterranean climates.

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Abstract

Within the future climate, which will bring longer and longer periods of high temperature in summer, exacerbating the heat island effect in cities, efficiency and sufficiency actions in buildings are strongly connected with enabling/hindering conditions in cities.
E.g. the use of night ventilation in summer to achieve comfort without using air-conditioning is possible if:
- noise is reduced by car-limitation and/or speed limitation policies
- night air temperature is kept low via increased presence of vegetation and "cool" finishing of urban surfaces
- the installation and correct use of external solar protections on buildings (and streets) is explicitly and correctly included in local building codes and its effective application actively supported and controlled at city level.

The reduction of the per capita building surface might be encouraged by the availability of attractive shared spaces within buildings and outdoor e.g. children having safe, autonomous access to common indoor/outdoor spaces for playing, the creation of cool open spaces for pedestrians at district level by shading streets and squares with tenso-structures (as traditional in parts of Spain and Portugal) and trees.
The use of climate and health friendly bicycle transport requires well designed spaces for bikes not only in the streets but also in each new and existing building.
We discuss how new «smart districts» and city re-design should and might include those and other efficiency and sufficiency-enabling physical features. We present a comprehensive matrix of interactions between building and district design for use by building designers and city planners with a focus on the emerging issue of summer comfort under a warming climate. A preliminary relevant question is if current policies are able to promote opportunities as the ones outlined above or there is a need to adapt those policies and how.

Glossary

Energy sufficiency is a state in which people's basic needs for energy services are met equitably and ecological limits are respected." Darby S., Fawcett T. (2018).

We present below a selection of main concepts, definitions and terminology on energy balance of a building, taken from European and International standards, in particular from EN-ISO 52000-1:2017(E). The following definitions are also available at the ISO Online Browsing Platform (OBP)[1].

"*energy need for heating or cooling*[2]**"** heat to be delivered to or extracted from a *thermally conditioned space* to maintain the intended space temperature conditions during a given period of time

[1] https://www.iso.org/obp/ui#search
[2] Note: in this paper we use *italics undelined* to identify terms which are defined in EN ISO standards.

"*energy need for domestic hot water*" heat to be delivered to the needed amount of domestic hot water to raise its temperature from the cold network temperature to the prefixed delivery temperature at the delivery point without the losses of the domestic hot water system

"*energy use for lighting*" electrical energy input to the lighting system

"*delivered energy*" energy, expressed per energy carrier, supplied to the *technical building systems* through the assessment boundary, to satisfy the uses taken into account or to produce the exported energy. (Note that *delivered energy* can be calculated for defined energy uses or it can be measured).

"*primary energy*" energy that has not been subjected to any conversion or transformation process. (Note that primary energy includes non-renewable energy and renewable energy. If both are taken into account, it can be called *total primary energy*)

"*non-renewable primary energy factor*" non-renewable *primary energy* for a given energy carrier, including the *delivered energy* and the considered energy overheads of delivery to the points of use, divided by the *delivered energy*

"*renewable primary energy factor*" renewable *primary energy* for a given *distant* or *nearby* energy carrier, including the *delivered energy* and the considered energy overheads[3] of delivery to the points of use, divided by the *delivered energy*

"*total primary energy factor*" sum of renewable and non-renewable *primary energy factors* for a given energy carrier

Introduction

According to the World Urbanization Prospects, in 2018 the 55 per cent of the world's population lived in urban areas and this percentage is going to reach 67 per cent by 2050. The challenge to create liveable and sustainable cities cannot be separated from an intertwined vision of designing buildings and infrastructures aware of the climate, the environment and the natural resources.

To reach this goal, sufficiency (and efficiency) actions should be at the basis of the strategy of planning and they should be shared by individuals and made possible through a collective / public choice by Cities, national governments, regulators and standardization bodies.

Energy efficiency policy (and its indicators at device level e.g. lumen/W or at macroeconomic level e.g. energy intensity of the economy) is a fundamental element of sound energy policy, but the expectations of a significant decoupling between economic activity, as measured by GDP, and energy use are currently not being met (see e.g. the new growth of *total primary energy use* in Europe starting in 2014[4], after several years in which a reduction has taken place, in correspondence with the economic crisis). At world level energy use has continuously been growing e.g. between 2000 and nowadays: new consumption has continuously been added, mainly from fossil sources, so that renewable energy has been an addition, rather than a substitution of fossil energy[5].

A more explicit objective of limiting *total primary energy* use (both from conventional and renewable sources, see EN ISO 52000 definition in the Glossary) requires the development and implementation of policies that promote both efficiency and sufficiency and that will enable options for low-impact living.

A scenario that incorporates and quantifies the effects of a systematic implementation of efficiency and sufficiency sufficiency policies/options is presented in (Grubler et al., 2018)

In this scenario the "final energy demand of 245EJ by 2050 … is significantly below current values and also below comparable scenarios in the mitigation literature …, including the lowest scenario of all those reviewed in the IPCC Fifth Assessment Report (274 EJ in 2050)"

A preliminary relevant question is if current policies are able to promote opportunities for absolute reduction of *total primary energy* use or there is a need to adapt our policies and how.

[3] By "energy overhead" it is meant the energy used for transporting the generated renewable energy to the building, e.g. the energy losses on the electric grid and energy storage for supplying wind energy from a *distant* wind farm to the building.

[4] https://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_saving_statistics

[5] British Petroleum statistical Review 2018, https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

Current challenges in the context of limiting total primary energy use in buildings

Cost-effective end-use efficiency technologies are available but investments in R&D and market deployment of these opportunities are funded at levels way below optimal (Wilson, Grubler, Gallagher, & Nemet, 2012). Sufficiency options are rarely considered while developing scenarios and energy policy.

In particular, the most urgent challenge is to strengthen policy actions in the context of summertime conditions under growing and extreme temperatures: energy use for space cooling is rapidly growing and the summer comfort issues are increasingly difficult to tackle due to climate change and exacerbation of heat island effect. According to J. Guiot, (CNRS Climate Laboratory, interview by FranceInter, 31 October 2016): "Heat waves like that of 2003 (70 000 deaths in Europe) could occur every 5 years in the most favourable scenario and every year in the scenario more unfavourable". Nonetheless, the regulation up to now is mostly addressed to winter (cold season) comfort and energy use, and it is guided by indicators of energy use/m^2. In many countries, summer comfort is still poorly considered by the average design practice, especially in the case of energy renovation of buildings for low-income families (e.g. social housing), where the attention is essentially placed on the energy savings for heating. However, the indoor environmental conditions of the buildings affect health, productivity and comfort of the occupants also during the cooling season and may enhance or decrement people's wellbeing. Often there is a poor description of comfort in the top regulation, no reference to the influence that the choice of the combination of parameters determining comfort conditions has on energy consumption. In most cases regulation, and hence everyday design practice, are not taking as a starting point a careful and explicit assessment of the needs of the occupants (Arens, Humphreys, de Dear, & Zhang, 2010).

A second critical aspect concerns the choice of the **indicators of the building performance** in regulations. There are signals that national regulation in some countries[6] and at EU level (EPBD recast, annex I) is moving towards using as unique indicator of building performance, the *non-renewable primary energy use*, thus implying that a very large use (in fact even an infinite) use of energy would be ok, as long as it is from renewable sources. This negates the limitations due to space, landscape preservation, raw materials use and the impact of corresponding mining and transport.

The indicator *energy needs for heating and cooling* (which expresses the quality of the thermal envelope and of heat recovery on ventilation) is poorly understood and often neglected. This aspect is linked to a recognized general lack of skill for most actors in the building sector (building users, building certification agents, building planners, construction industry, policy makers). A correct use of the nomenclature, definitions and indicators is still missing among the different stakeholders and there is a general difficulty in clearly identifying the energy levels (*energy needs for heating, cooling, hot water, energy use for lighting, total primary energy use, non renewable primary energy use*) defined in EN-ISO standards. The current approach of using separate national nomenclatures and definitions in different Member States, and sometimes within different regions of a Member State, creates in fact a market barrier for energy saving envelope materials and components, efficient technical building systems and design strategies for new constructions and retrofits. Finally costly access to basic info is a barrier to effective design. E.g. the EN-ISO standards and their national declinations are a large number, and are not available for free in spite of being an essential part of regulation. Their large diffusion would on the contrary be a basis for good practice and for the establishment of clear cut communication based on common definitions of energy levels, physical properties, floor area, etc, making easier the transfer of best practices and reducing costs due to miscommunication, errors in design and construction that need then to be corrected a posteriori,…

In general we argue that there is insufficient public investment into capacity building and quality control and a difficulty to invest in training and continuous training by private companies.

As for energy policies currently in place to promote better performance of buildings, a number of them rely on market signals via labelling etc. that mostly transfer the responsibility of action on individual final owners and users of buildings, which are expected to modify their actions in the market based on those signals.

E.g. energy labelling of buildings, mandatory heat cost repartition based on heat metering or heat allocation, etc all assume explicitly or implicitly that:

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[6] Interim report of the project Affordable Zero Energy Buildings, deliverable 2.1., to be published in May 2019

- labelling and heat allocation will be performed with adequate skill and hence will be correct and perceived as correct and reliable

- economic cost savings or gains are the main motivation for action

- other factors (e.g. location with respect to city center and services), are less or same order of magnitude of importance in the choice of how to select and operate a building

- final users (and building designers and construction industry) can easily understand the message conveyed (does the building label indicate *total primary energy, non-renewable primary energy, energy needs*?, and what is the meaning of those indicators…? Does it give indications about thermal comfort?)

Other energy policies are based on price signals. Policy choices to use tariff making (in the segments where it is still possible) to promote penetration of electricity use for possibly "efficient" devices (e.g. heat pumps, electric cars,) has led some countries (e.g. Italy, France, …) to give up the existing (Italy) or proposed (France) progressive tariffs (those tariffs where the price of the single unit of energy grows with the number of units used in a given period, generally a month, see e.g. progressive tariffs applied by the main Energy Utilities in California[7]). But the objective of increased use of heat pumps might not deliver a reduction in energy use if building fabric and heat distribution are not adapted at the same time and if air is used as a source-sink rather than the ground or a large water body (Harvey, Hafemeister, Levi, Levine, & Schwartz, 2008). The objective of higher penetration of electric mobility but still through individual cars is in contrast with other potentially more benign mobility options (public transport, active mobility and combination of the two) and in contrast with other uses of space which are needed to enable sufficiency (and efficiency) actions in buildings (see below).

Overall instruments purely based on market/price seem, at least tin this area of application, to be weak in terms of:

- being able to achieve effects in isolation from public investments in effective controls and in capacity building
- being able to fine tune the evolution of the market towards the (stated) goals

Potential answers to the above policy challenges

In the following we try to discuss how to address the problems highlighted in the previous section, identifying the actions needed by individuals and the public choices/policies that are needed to enable the possibility to enact those actions.

Regulation and summer comfort

The possibility to apply (as a user of a building as much as a designer of a building) efficiency/sufficiency measures such as night ventilation in summer nights and use ceiling fans during the day instead of (or to reduce use of) air-conditioning depends on explicit recognition at the regulation level of the following issues:

1) the same level of thermal comfort, as measured e.g. via the index Predicted Mean Vote (PMV), can be achieved via various combinations of physical parameters, each with different values of *energy need for cooling* and *energy need for dehumidification* [Table 1 and Figure 1, (Dama et al., 2014), (Pagliano & Zangheri, 2010)].

Table 1. Various combinations of operative temperature (T_{op}), Relative Humidity (R.U.) and air velocity (v, obtained e.g using ceiling fans or individual fans) leading to the same expected comfort sensation Predicted Mean Vote (PMV). The same level of metabolic activity (met) and clothing insulation level (clo) is assumed in the four cases (Dama et al., 2014), (Pagliano & Zangheri, 2010)

SIMULATION	Top	R.U.	v	PMV	clo	met
	°C	%	m/s	-	-	-
Reference case	26	60	0.01	0.5	0.5	1.2
Case 1	25.7	70	0.01	0.5	0.5	1.2
Case 2	27.3	70	0.5	0.5	0.5	1.2
Case 3	27.6	60	0.5	0.5	0.5	1.2

[7] http://energy.sia-partners.com/progressive-tariffs-electricity

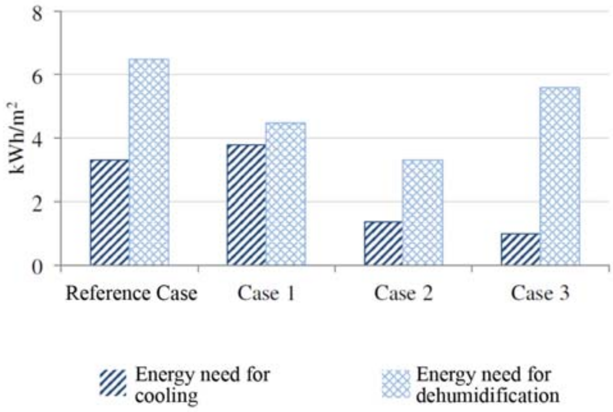

Figure 1. Influence of the choice of operative temperature (Top), Relative Humidity (R.U.) and air velocity (v) on the energy need for cooling and the energy need for dehumidification. (Dama et al., 2014), (Pagliano & Zangheri, 2010)

2) The choice of the comfort category (I, II or III according to EN 16798-1, formerly known as EN 15251, or A, B, C according to ASHRAE 55) which is aimed at by the building design and/or controls strongly affects energy use (Sfakianaki et al., 2011)
3) A number of research works show that Comfort category I (A), which is the more energy demanding, cannot be perceived subjectively (Arens et al., 2010) and it is below the accuracy of measurements (d'Ambrosio Alfano, Palella, & Riccio, 2011). In the EU standard (EN 15251) category I (A) is reserved to buildings occupied by fragile people (handicapped, elders, hospitals…), but it may nevertheless be perceived and presented as the "best" condition.
4) An important parameter affecting comfort in the warm season is the insulation level of clothing and of furniture, as e.g. office chairs (both measured in the unit *clo* and with indicative values reported e.g. in ISO 7730). Regulation should actively and explicitly promote the adoption of dressing codes where light clothing is the norm rather than the exception (see e.g. the coolbiz programme in Japan[8])

Recent revisions of international standards have updated the definitions of comfort and ways to use them in designing and evaluating buildings. ASHRAE Standard 55:2017 and EN 15251:2007 have introduced the Adaptive model to be used in naturally ventilated buildings and ISO 7730:2005 and EN 15251 have introduced the concept of comfort categories based on different ranges of Predicted Mean Vote (PMV) or operative temperature around the neutral conditions. Recently ASHRAE has published its Global Comfort Database II / Földváry et al., 2018) where validated additional data on real buildings are collected and made available via a graphical interface and brings new evidence to the adaptive comfort model. This comfort model, which proposes a linear positive correlation of summer indoor comfort temperature with the average outdoor temperature in the previous week, allows for lower energy use when compared to a restrictive interpretation and application of the PMV model (Pagliano & Zangheri, 2010).

Indicators of building performance

A situation where that all the actors involved in development of efficiency/sufficiency measures in the field, regulators and policymakers use consistently the same set of physical concepts, definitions, nomenclature would ensure better final results in terms of comfort levels and energy use and would be a prerequisite for devising clear guidelines for design and construction focused on allowing sufficient behavior and operation.

The necessity of using a unified nomenclature has been stated very explicitly in a report commissioned by the European Commission on ZEB definition (Hermelink et al., 2013), has been proposed at key steps of the entire

[8] https://en.wikipedia.org/wiki/Cool_Biz_campaign

process of revision of the Energy Performance of Building Directive by eceee experts (eceee Board & eERG, 2015) and supported in scientific literature (Attia et al., 2017) and EU projects[9].

The EPBD recast finally approved in 2018 takes up partially those suggestions but a degree of uncertainty about main definitions and nomenclature is anyway present, which should be addressed in drafting the guidelines for application and in the National implementation processes.

Furthermore, the revision of the main commas of Annex I of the EPBD removes the double indicator of performance of buildings which was present in the previous (2010) version (" The energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the *heating energy needs* and *cooling energy needs* (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs.

The energy performance of a building shall be expressed in a transparent manner and shall include an energy performance indicator **and** [bold by the authors] a numeric indicator of primary energy use, based on primary energy factors per energy carrier…")

and reduces it only to one, namely "primary energy" (not better specified in the texts). This is in contradiction with the Standard ISO EN 52000 produced under Mandate 480 by the EU Commission. In fact, the Standard states: *"the use of only one requirement, e.g. the numeric indicator of primary energy use, is misleading".*[10]

The Standard ISO EN 52000 explains which indicators are needed and why. Summarising:

- *energy needs for heating and cooling* (for quantifying and promoting the reduction of energy losses through the envelope and ventilation)
- *total primary energy* use (for quantifying and promoting the reduction of inefficiencies in the systems - e.g. avoid burning biomass in an inefficient burner)
- *non renewable primary energy* use (for quantifying and promoting the reduction of the non-renewable fraction within total primary energy use)

The indicators *energy needs* and *total primary energy* do respond to the "energy efficiency first" principle and to the aim of quantifying the effect of sufficiency actions, while the parameter *non renewable primary energy* responds to the objective of "increasing the share of renewables".

We have developed a series of simplified graphical representations that we used during the debate on EPBD revision to offer advice to the Estonian Presidency of the council of Ministers, to DG-Energy and various stakeholders and NGOs. We observed during those interactions how a better understanding of the physical concepts and a commonly agreed language might be a major pre-requisite for developing transparent and ambitious policy.

[9] www.azeb.eu

[10] https://www.eceee.org/policy-areas/Buildings/cut-energy-needs-first/

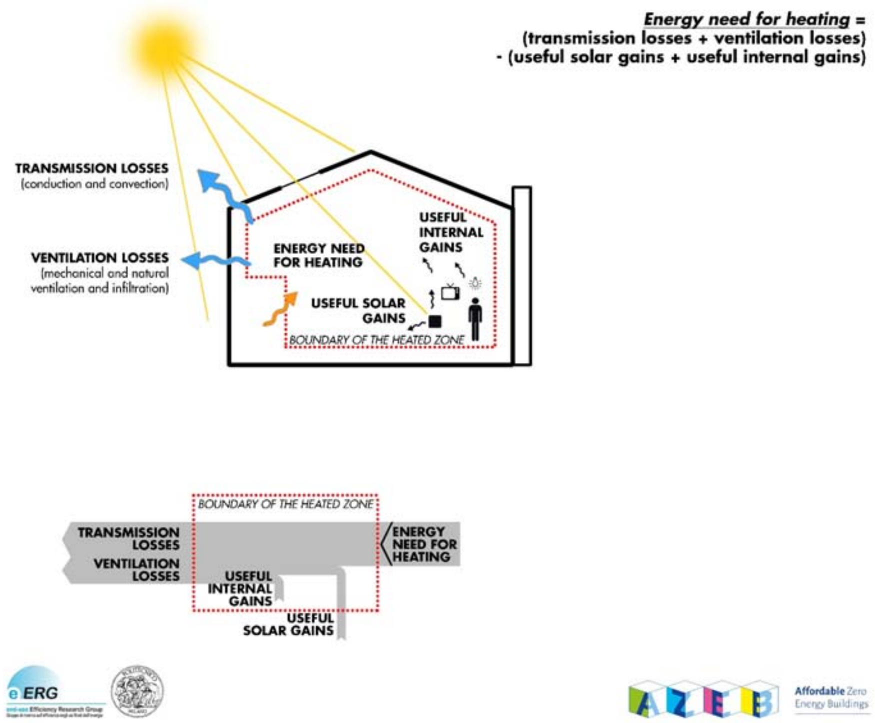

Figure 2. Visualisation of the concept of "<u>energy need for heating</u>"

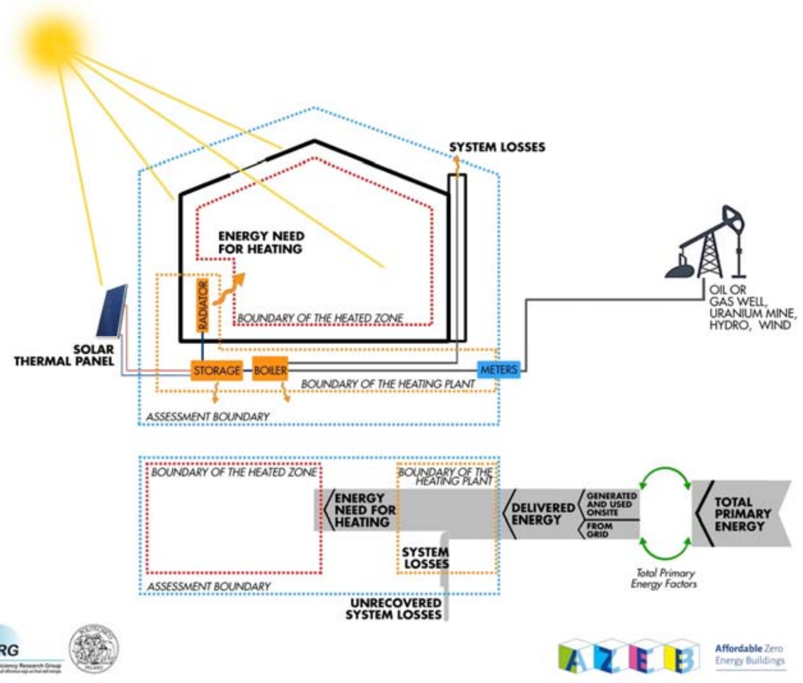

Figure 3. Visualisation of the concept of "<u>total primary energy</u>", case where the energy service considered is space heating, provided by a boiler and <u>on-site</u> solar thermal panels.

Building codes and city planning need to be integrated to avoid hindering options for efficiency/sufficiency action.

Design of buildings as guided by building codes and city planning are still to large extent separate issues. On the contrary, sufficiency (and efficiency) actions in buildings are strongly connected with enabling/hindering conditions in cities.

Already in the 1940s the Egyptian architect Hassan Fathy designed and helped the construction of the entire village of New Gourna[11] near Luxor, reviving traditional techniques of orientation, ventilation, screening and shading at building and district level.

In the district of Florés Malaca, a group of buildings offers a recent example[12] of holistic planning of buildings and districts. Orientation of buildings and shape and openings of each apartments take advantage of dominant Alisee wind for achieving cross ventilation and cooling the *building fabric* at night. Ceiling fans are integral part of the comfort concept. The presence of cars has been limited to an underground parking in order to achieve an acoustically quiet environment allowing natural ventilation without acoustic discomfort.

Figure 4. District of Florés Malaca, Le Port, La Réunion, and design of the apartments enabling effective cross ventilation

Recent actions in large cities (e.g. Paris) aimed at creating opportunities for walking and cycling (in parallel to limiting individual motorized vehicles use and speed) and increasing green areas might allow for better opportunities also in the use of buildings. Solar protection and street level is relatively common in some towns in South of Spain and Portugal and by lowering the air temperature in the street canyon might allow for better conditions for night summer ventilation. The use of spaces for introducing vegetation and low solar absorbtance surfaces - if practiced at large scale - can reduce the heat island effect (Kleerekoper, van Esch, & Salcedo, 2012) and maintain the potential for using night ventilation as an effective passive cooling technique.

[11] https://www.wmf.org/project/new-gourna-village

[12] http://www.smartweb.re/envirobat/files/fiches_envirobat_reunion/logements/FICHE_ENVIROBAT_Reunion_FLORES_MALACCA.pdf

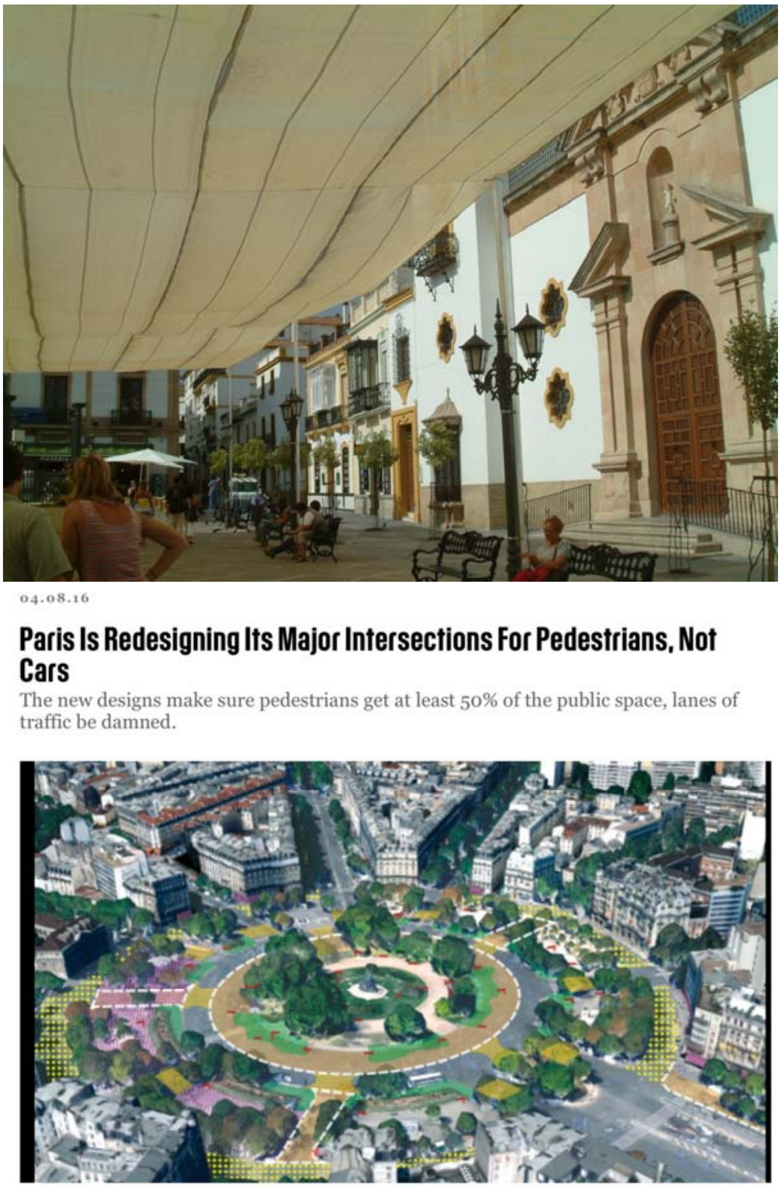

Figure 5: examples of design/redesign of streets and squares in Andalusia, Spain (Photo by L. Pagliano), and France (Source: https://www.fastcompany.com/3058685/paris-is-redesigning-its-major-intersections-for-pedestrians-not-cars) for reduction of air and surface temperatures in summer, to the benefit of outdoor comfort and of enabling options for passive cooling of buildings

Planning a building project at the scale of an urban block gives more possibilities to improve performance and reduce cost compared to designing single buildings independently.

This includes for instance maximization of winter solar exposure, reduction of heat losses by increased compactness, reduction of environmental impacts of materials and costs by mutualizing walls, increased efficiency of energy systems thanks to e.g. district heating, centralized biomass boiler etc.

Green spaces between the buildings, on the roof and some facades help reduce the outdoor air and radiant temperature and hence create better conditions for effective summer night ventilation.

Common spaces favor conviviality and cohesion and may reduce the need for excessively large private (conditioned) spaces.

A provision for spaces adequate to line drying outdoors (on facades, balconies, roofs) and well designed for convenience and aesthetic can enable this practice, very relevant in terms of energy saving (drying a kg of clothes indoors or with a drying machine can be 3 to 5 times more energy expensive than washing it).

During the recast of EPBD in 2017 there has been strong pressure to include provisions for recharge points for electric cars in each new building and retrofit project and articles with requirements in this direction have been introduced. It was the first time mobility issues were considered in EPBD, but the point of view has been a single technology and a narrow view of what mobility is. An amendment proposed by the authors of this paper in collaboration with European cyclists federation and some MEPs proposed that "Member States shall ensure that in all new buildings and in all buildings undergoing major renovation, at least a space for bicycles, electric bicycles and pedelec, cargo-bicycles, walking frames, wheel-chairs and push-chairs is created; the space shall be common, covered, theft-protected, free of architectural barriers and proportional to the number of users of the building; the space could be created nearby the building, in case of documented technical impossibility."

The amendment has been rejected by the ITRE commission and only in the preambles of EPBD there is a recognition that "When applying the requirements for electromobility infrastructure provided for in the amendments to Directive 2010/31/EU, as set out in this Directive, Member States should consider the need for holistic and coherent urban planning as well as the promotion of alternative, safe and sustainable modes of transport and their supporting infrastructure, for example through dedicated parking infrastructure for electric bicycles and for the vehicles of people of reduced mobility.", where the variety of non-motorized and light modes of transport has been compressed to just **electric** bicycles and a vague recommendation.

There is a lack of recognition of the strong interaction between use of space in the cities for individual motorized mobility, performance of buildings, air quality, which needs to be addressed. A few data from (Timmers & Achten, 2016), might elicit questions on the need of a deeper understanding of the effects of the mobility choices we are facing:

- A large fraction (50-85% and up to 90%) of traffic generated PM10 and PM2,5 is not due to the exhaust emissions by the motor, but rather to non-exhaust emissions (brake wear, road wear, tyre wear and road dust resuspension)
- Non-exhaust emissions are found to be proportional to the mass of the vehicle
- Electric Vehicles emit the same amount of PM10 as modern gasoline and diesel cars. Analysis that compare PM2.5 emissions, conclude that EVs bring about a negligible (1 to 3%) reduction in PM2.5 emissions compared to recent internal combustion engines.

An overview of interactions between districts and buildings favoring efficiency and sufficiency actions and the necessary supporting regulation is presented in table 2.

Table 2: interactions between districts and buildings favoring efficiency and sufficiency actions and supporting regulation

Sufficiency actions in building →	Summer night ventilation and ceiling fans (7W/m2) Rather than Air Conditioning (150W/m2)	Summer night ventilation Rather than Air Conditioning	Adequate m2 per capita floor space	Adopt "sufficient" mobility modes: bicycle, walk, public transport	Line drying and water / hot water saving
In order to perform sufficiency actions, inhabitants would need: →	Silence at night, clean air	External air temperature <20°C at night	Pleasant common indoor/outdoor spaces (shared guest rooms, music rooms, office space, playing spaces for children,…) to reduce the need for individual volumes	Easy access to services, schools, work, Independence for children and elders	Well designed spaces for line-drying, Water saving devices
Presently cities create constraints →	noise, mainly from cars and motorcycles. PM10, PM2,5 pollution and other air contaminants	asphalt, city canyons	inhospitable districts, obligation for car parking spaces at buildings, free car parking on strrets	distance between functions, unacceptable risks for cyclists, pedestrians, handicapped	Dust in air
Cities should offer potentialitie →	Car-free residential districts, zones at 20 or 30 km/h	white/cool surfaces. Geometries facilitating air movement. Water surfaces & urban vegetation	walkable, cyclabile districts, green spaces, spaces for playing, spaces in the building for common activities	equitable access to street space, equal access to various transportation modes	Information campaigns on water saving devices, and on the high quality of drinking water from the tap
Legislation and Regulation should address →	Objective and adequate temperature and humidity set-points in regulation	Mandatory white/cool surfaces, mandatory external solar protections (as e.g. in Switzerland)	Minimum requirements of green spaces, of common spaces for meetings	EPBD (and National build codes): mandatory space for bicycles… in buildings	Mandatory spaces for line drying, mandatory labelling of low-flow water devices

Price signals

We report in Figure 5 the example of progressive tariffs in California. Sufficiency actions that reduce energy use always cut the most expensive kWh, thus giving an economic reward and (probably more importantly) the message that energy use has an environmental impact whichever the source.

Recently the progressive features have been slightly modified. https://www.pge.com/en_US/residential/rate-plans/rate-plan-options/tiered-base-plan/tiered-base-plan.page

Italy has had in place for decades a tariff for electricity for households, featuring a price growing with monthly energy use (kWh/month) and with contracted power (kW) (Pagliano, Alari, Pindar, & Ruggieri, 1999). This might explain a series of efficiency/sufficiency choices (low penetration of direct electric resistance space heating, low penetration of clothes dryers, …). In the case of single appliances or devices the price signal, constantly maintained over decades, seem to have had a significant impact. The introduction of heat pumps would need a separate circuit and meter anyway, since most contracts of households are presently physically limited to 3 kW, and for that meter a distinct tariff structure may be set up, as e.g. done in PG&E jurisdiction..

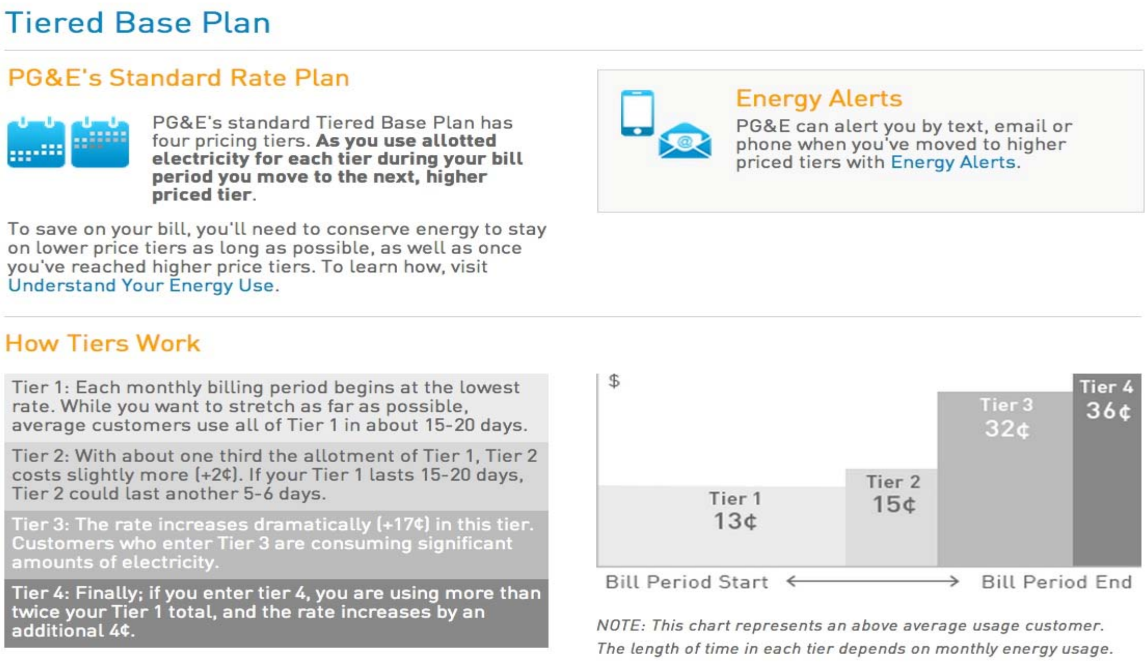

Figure 5.Progressive tariff for domestic customers in part of California (PG&E)

Conclusions and acknowledgments

To tackle the challenges linked to future climate and its impact on buildings and cities, it is important to introduce policies which enable options for efficiency and sufficiency actions. Enabling (or hindering) conditions are key for the success of an adaption of behavior on a scale large enough for a significant reduction in *total primary energy* use.

Sufficiency actions in buildings, especially in summer are strictly linked to the city conditions, in term of outdoor temperature, noise level and safe and easy access to facilities for cycling, walking, line drying. The amount of energy which might be saved through these actions is often more relevant than via improvement of pure technical efficiency. Yet energy policy and practice is addressing those areas to a very limited extent, when not ignoring them altogether.

We are seeing some advances in the field of setting comfort objectives. Relatively strict comfort objectives have been applied in the past. However recent standards have embraced the results of decades of research on comfort and included the adaptive comfort model and more explicit ways to exploit some flexibility in the use of PMV. This can enable design options which better fulfil comfort expectations of building occupants and at the same time allows for the reduction of energy use, technical building size and costs.

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