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Buildings: The new energy nexus

Le bâtiment, nouveau nœud énergétique

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ABSTRACT

Buildings are the largest contributors to households' energy footprints. If both the energy for household mobility and the embodied energy are added to the energy for heating/cooling, domestic hot water, lighting, buildings are by far the main problem of energy consumption in France. This paper presents a review of the evolution of the main drivers of CO_2 emissions by buildings in France. Eventually, the paradox of the effect of density is discussed. Lower density of cities increases the energy spent per inhabitant, in particular for transport, but may also increase the production of low-carbon renewable energies, shifting the global energy balance and influencing the prospective studies of future, energy efficient, smart cities.

RÉSUMÉ

La consommation d'énergie par les bâtiments est un contributeur très important à l'empreinte climatique des ménages. Si on y ajoute l'énergie crise nécessaire à sa construction et l'énergie des transports, qui dépendent directement de sa localisation, alors la question du bâtiment devient le point focal de la problématique Énergie. Cet article présente une revue de l'évolution des différentes composantes des émissions de gaz à effet de serre associées au bâtiment dans le mix énergétique de la France. En conclusion, le paradoxe de l'effet de densité des villes est présenté. Les faibles densités induisent une augmentation de la consommation individuelle d'énergie, en particulier pour le transport. Mais elles permettent aussi une augmentation de la production d'énergies renouvelables réparties, ce qui modifie le bilan énergétique et la vision prospective des villes du futur, économes en énergie et intelligentes.

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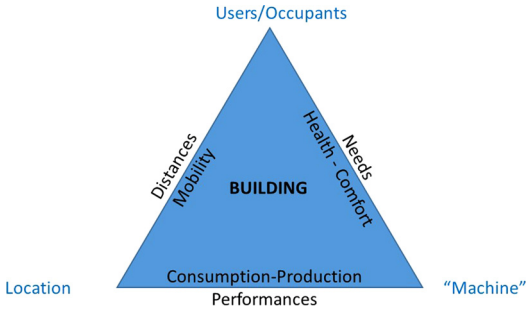

Fig. 1. Location, "machine", and users.

1. Introduction

Buildings are the witnesses of everyone's life, either at home for several aspects: private life, patrimony, family, relationships with neighborhood, or in other buildings such as school for learning, industrial and tertiary for working or commercial for shopping. Indeed, we spend 80% of our time inside buildings, which are traditionally the main places of consumption of all kind of products and where many goods consume energy to fulfill the occupant's needs. More recently, buildings and the built environment are shifting to the energy production side, mainly using photovoltaic, wind and biomass, a kind of "energy gardening".

Therefore, buildings, either single-family houses or collective housings or working places or culture and leisure locations can be investigated in different ways: technically, sociologically, or geographically.

"A house is a machine for living", said Le Corbusier in 1925. This very technical approach is often opposed to a very sensitive if not sensual approach, as underlined by Hölderlin's verse "Man lives as a poet" [1].

Beyond the "machine" and the poem, the first identifier of a building remains its address and, as generally claim real estate agents, "location first, location second, location third".

Fig. 1 briefly shows how location, "machine", and users interact and consequently contribute to energy consumption and GHG emissions during their life cycle.

Placing users or occupants at the center of the building environment is the leitmotiv of many actors of the construction sector [2], whether in residential or commercial or industry sectors.

Without looking in details the Maslow's pyramid of needs and by focusing only on residential sector, the living space must provide the basic needs for living, which are as follows: breathing, drinking, and eating [3]. This means enough fresh air to breathe, enough water to drink and foods for eating, but also "foods for brain & spirit" thanks to modern communications networks and services such as "cloud", which are growing energy consumers.

Even though most people have a sedentary lifestyle, mobility is an important aspect of their way of life, whether the chosen mobility for leisure and culture, or the mandatory one to go to working places, schools, or shops. Whether TV sets and more recently connected mobile devices may sometimes answer those needs without physical movements, they are also encouraging physical mobility, for longer range trips, either for work or leisure.

Finally, the location, the performance of machine named "building", and the efficiency of the equipment installed by the occupants, are the three pillars of the energy consumption that is considered in this paper.

What about energy? Generally, energy is claimed to be consumed by buildings, even though the technical object named "building" is responsible for a very little amount of energy consumption during its operational life [4], but much more during the conception, construction [5], and de-construction phases. In fact, most of the energy is consumed by occupants, despite they have no direct contact with energy vectors (fuel, gas, electricity) [6] and more precisely by equipment and goods offering services to them such as: I am hot/cold, I am cooking, I am using hot water for showers, washing and cleaning, I need light, fresh air from ventilation, I need to fill the tank of the car… Consequently, occupants do not feel directly responsible for energy consumption, as energy is consumed by equipment and, more generally, by buildings. Besides, it is interesting to note that energy consumption is counted in kW h/m^2 yr and not in kW h/person·yr. Moreover, if services were provided without fossil energy, people would not do matter.

2. Key numbers of energy/CO_2 for France

France is extremely dependent on imports for its primary energy: 98.5% of its oil, 98% of its natural gas, all its coal and uranium are also imported. Energy contribution to the international trade balance was as high as 32.5 billion € in 2015, and even 70 G€ in 2012 [7]. Due to its predominant position for transport needs, oil is taking the main part (64%) in GHG emissions, when gas contribution is only 24% and coal produces the remaining 12% [8]. In terms of primary energy, fossil energy (coal & oil) and nuclear energy (uranium) have an equivalent share, but in final energy terms, the weight of fossil energies is 64% and that of electricity only 25%.

In Table 1, the "transportation row" corresponds to all transportation systems (personal vehicle, public transportation, etc.), and it is assumed that "buildings" gather all types of buildings (public building, residential houses and dwellings,