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High tech startup creation for energy efficient built environment

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ABSTRACT

The civil engineering area has long been known for not being associated with high tech startup creation. This is a sign of the low innovation which is confirmed by its low patenting level thus contributing to undermine the prestige of this area. Still this area has an important role to play given the environmental impacts of the construction industry that will be exacerbated in the next decades due to the growth in world population, each day there are about 220,000 new inhabitants which means more than 9,7 billion people by 2050 and 11,2 billion by 2100. A direct consequence of such growth relates to a steady increase of energy consumption which is the source of two-thirds of global greenhouse-gas emissions. The building sector is responsible for high energy consumption and its global demand is expected to grow in the next decades. Between 2010 and 2050 the global heating and cooling needs are expected to increase 70% in residential buildings and 90% in commercial buildings. Major energy efficiency measures are therefore crucial to reduce energy consumption and greenhouse-gas emissions of the building sector. This includes development of new technologies and materials to improve greatly energy efficiency. Since information derived from knowledge is critical for individuals to transform innovative ideas into commercial products and services, this paper reviews recent developments on nano and bio based innovations important for an energy efficient built environment. This review may contribute to enhance the innovation and patenting activity in civil engineering. This may help to foster the creation of high tech startups for an energy efficient built environment.

1. Introduction

Civil engineering is known as an area mainly concerned with directing the great sources of power in Nature to the use and convenience of man trough the construction of large and public infrastructures (bridges, dams, airports, highways, tunnels etc etc etc) by large construction companies. This area has never been associated with high tech startup creation. This is a sign of the low innovation level which is confirmed by its low patenting level. In the USA the patenting level on civil engineering falls behind other areas [1]. According to Keefe [2] very few civil engineers take their innovations to the United States Patent and Trademark Office (USPTO), in contrast with the considerable number of electrical and mechanical engineers. This author provides data that show that the patenting in civil engineering area is 7 times less than in mechanical engineering and 10 times less than in electrical engineering. A recent and worldwide study [3] confirms the prone patenting nature of other more innovative areas than civil engineering. This low innovation level undermines the prestige of civil engineering and contributes to explain the reduction in undergraduate applications to civil engineering courses [4–8]. Nedhi [9] stated that civil engineering is not traditionally viewed as “high tech” engineering. Even in India this area is viewed as a low tech one [10]. As a consequence low starting salaries are normal in this area [11]. As construction enterprises have low productivity [12] they have to compete for lower bids with consequent lower profit margins [13]. They also have to cope with an increasing and fierce Chinese competition already capable of building a 30-story in just 15 days [14] which means that construction enterprises will in future have less and less financial possibilities to offer high and attractive pay checks to civil engineers. Nevertheless, civil engineering has an important role to play given the environmental impacts of the construction industry that will be exacerbated in the next decades due to the growth in world population. Urban human population will almost double, increasing from approximately 3.4 billion in 2009 to 6.4 billion in 2050 [15] and recent estimates on urban expansion suggest that until 2030 there is a high probability (over 75%) that urban land cover will increase by 1.2 million km^2 [16]. Redirecting the focus of civil engineering from the construction and rehabilitation of grand infrastructures to high tech built environment related areas and the needs of individual home users will enlarge the number of future potential clients creating a market that may foster high tech startup creation. Information derived from knowledge is critical for individuals to transform innovative ideas into commercial products and services. Distinguished Prof. Willian Baumol [17] has stated that promoting

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entrepreneurship and small firms would play a critical role for economic prosperity. Also in the current context of high graduated unemployment rates that will be more dramatic in the next decades [18,19], start-up creation could become a way to solve this serious problem. This paper reviews recent developments on nano and bio based materials and technologies. These can not only contribute to a more eco-efficient construction industry but also to enhance the innovation and patenting activity in the field of civil engineering creating a knowledge context important for entrepreneurship. This review may contribute to enhance the innovation and patenting activity in civil engineering. This may help to foster the creation of high tech startups for energy efficient built environment.

2. The future of civil engineering on the context of sustainable development

An important sustainable development serious problem which is directly related to the field of civil engineering concerns resource inefficiency. Over the 20th century, the world increased its fossil fuel use by a factor of 12, whilst extracting 34 times more material resources [20]. During the last century, materials use increased 8-fold and, as a result, Humanity currently uses almost 60 billion tons (Gt) of materials per year [21]. The most important environmental threat associated to its production is not so much the depletion of non-renewable raw materials [22], but the environmental impacts caused by its extraction - namely extensive deforestation and top-soil loss, instead. In 2000, the mining worldwide activity generated 6000 Mt of mine wastes to produce just 900 Mt of raw materials [23]. This means an average use of only 0.15%, resulting in vast quantities of waste, whose disposal represents an environmental risk in terms of biodiversity conservation, air pollution and contamination of water reserves. Since materials demand will double in the next 40 years, the environmental impacts will therefore increase in a drastic manner [20]. The global construction industry consumes more raw materials (about 3000 Mt/year, almost 50% by weight) than any other economic activity, which emphasizes its unsustainable character. For instance, concrete is the most widely-used construction material on Earth, currently used at a level of about 10 km^3/year [24], compared to 2 km^3 of fired clay, 1.3 km^3 of timber, and 0.1 km^3 of steel (Flatt et al. [25]) [24]. These astonishing figures show the importance of concrete in the context of material efficiency. Additionally this industry is associated to massive carbon dioxide gas emissions. The main binder of concrete, Portland cement, is responsible for almost 80% of the total CO_2 emissions from concrete, which in turn make up around 6 to 7% of the planet's total CO_2 emissions [25]. This is particularly serious in the light of the current concerns around climate change. It's important to mention that 2016 was the first year with atmospheric CO_2 concentrations above 400 ppm all year round (Betts et al. [140]) and, more worryingly still, the fact that the demand for Portland cement is expected to increase by almost 200% between 2010 and 2050, reaching a level of 6000 million tons/year [26]. Also, in the next years the construction industry will keep on growing at a fast pace. China will need 40 billion square meters of combined residential and commercial floor space over the next 20 years - equivalent to adding one New York City every two years [27]. In the US, where about 27% of all highway bridges are in need of repair or replacement, the needs for infrastructure rehabilitation alone are estimated to be over 1.6 trillion dollars in the next five years [28]. Between 2012 and 2017, India will invest 1 trillion dollars in infrastructures [10]. In Europe, UK's infrastructure will need over 65–80 billion dollars every year, between now and 2030 in order to maintain current levels of service [29]. Another very important issue concerns energy consumption that has been steadily rising in the last decades (Fig. 1) and will keep on rising no matter what [31]. This is due not only to the increase in world population but also to the fact that electricity consumption per capita in low and middle income countries will increase as a consequence of future higher income and related higher comfort standards. This is aggravated by the fact that only 21% of world electricity generation was from renewable energy in 2011 with a projection for nearly 25% in 2040 [32]. As the source of two-thirds of global greenhouse-gas emissions, the energy sector is therefore pivotal in determining whether or not climate change goals are achieved. Climate change is one of the most important problems faced by the Human species being associated to the rise in the sea level, ocean acidification, heavy rain, heat waves and extreme atmospheric events, environment deterioration and wildlife extinction, health problems and infrastructure damage [33]. The building sector is responsible for high energy consumption and its global demand is expected to grow in the next decades. Between 2010 and 2015 the global heating and cooling needs are expected to increase by 70% in residential buildings (Fig. 2a) and 90% in commercial buildings (Fig. 2b). Energy efficiency measures are therefore crucial to reduce GHG emissions of the building sector. Recent estimates [35] state that energy efficiency concerning buildings heating and cooling needs could allow a reduction between 2–3.2 $GtCO_2e$ per year in 2020. In Europe, buildings are responsible for more than 40% of the energy consumption and greenhouse gas emissions [36] and the average energy efficiency improvement at EU level, fell from 14% in the period 2000– 2008 to 6% in the years 2008–2013 [37]. Fig. 3 shows the energy efficiency trends for households in several EU countries. The recasting of the Energy Performance of Buildings Directive (EPBD) was adopted by the European Parliament and the Council of the European Union on 19 May 2010. The recast set 2020 as the deadline for all new buildings to be ‘nearly zero energy’; for public buildings, however, the deadline is even sooner – by 2018. Come what may, the fact is that new buildings have limited impacts on overall energy reduction as they represent just a tiny fraction of the existing building stock [38]. This shows the importance of building retrofitting for attaining ambitious energy efficiency goals. Building energy efficiency retrofitting is also crucial to tackle the important social problem of energy poverty. This problem affects between 1.3 billion and 2.6 billion people from underdeveloped regions of the world. Between 50 and 125 million people in Europe alone suffer from energy poverty [39]. This has important health consequences for children and older people leading to an increase in medical costs. Infants, living in energy poor homes are associated with a 30% greater risk of admission to hospital care. Indoor cold is also highly correlated to premature

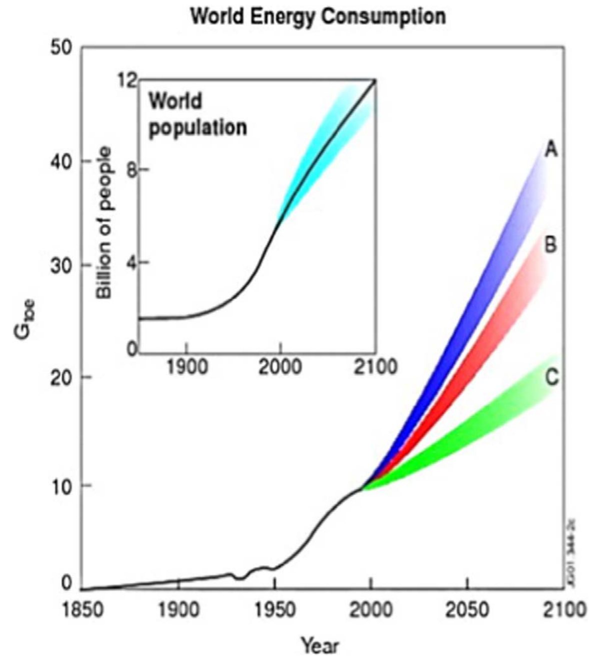

Fig. 1. World energy consumption in the past 150 years [30].