Economic barriers to green innovations in Morocco: the case of a zero-energy house

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Abstract. Building with a reduced ecological footprint has become a major topic in the energy and economic debate in Morocco. This article aims at analyzing the economic barriers facing the integration and diffusion of environmental innovations in the building sector in Morocco. The concept of environmental innovation is taken as a conceptual framework for our analysis. We present a case study of the integration of innovative technical solutions: it concerns the use of a bio-sourced material “hempcrete” (as a green input) and an innovative system (Curved Solar Panels) for the construction and the energy production of a zero-energy building. The results show that these innovative solutions cannot easily be adopted and generalized given the fact that their cost remains high compared to conventional solutions. In addition, at the macroeconomic level, several barriers can hamper the generalization of these solutions in Morocco.

1. Introduction

Although it contributes to the economic growth by 1 million jobs and 7% of the GDP[1], building in Morocco remains a sector with multiple negative externalities. In fact, the building sector is responsible for 33% of energy consumption (25% for residential and 8% for tertiary sector). Indeed, the residential building is responsible for 12% of greenhouse gas emissions[2]. It is a very energy-intensive sector throughout the whole value chain: from extraction, to demolition, passing by construction, operation, maintenance, repair, renovation / rehabilitation. In this context, in order to overcome these negative externalities and reduce energy consumption, Morocco has initiated the energy transition process with a very high potential of renewable energies (especially solar) and the integration of eco-innovations, however, the use of these resources and the integration of these innovations are still very limited: the production of renewable energies does not exceed 8.8% of primary energy consumption and the budget allocated to R&D does not exceed 0.6% of GDP.

In this sense, several questions arise: Can the use of innovative building materials, new processes and high-performance systems be beneficial in terms of reducing the ecological footprint on the environment? Is the cost of these innovations affordable? Is the generalization of the integration of innovative technical solutions possible? And what are the economic barriers that would hinder the integration and generalization of these technical alternatives? In order to answer these questions, we begin in the first section with a brief review of the concept of environmental innovations and its specificities. The second section is dedicated to the presentation of the integration of innovative technical solutions. In the third section, we finally discuss the economic barriers that could hinder the
dissemination and generalization of innovative technical solutions in the Moroccan building sector by focusing on the case of the Zero Energy House as an example.

2. Methods

Since the mid-1990s with the signature of the Kyoto agreement on the environment protection and climate change, the interest on sustainability gained more and more importance. In this context, many researchers in the field of environment and energy economics started working on the concept of environmental/green innovation. The first step was to give a sense to this concept by defining it. In this context, Malamande defines environmental innovations as "any modification" in processes and products which reduces the impact on the environment compared to the processes or products for which they have been substituted[3]. ForHemmelskamp[4], it is defined as an innovation that prevents or reduces “anthropogenic pressure” on the environment, remedies damage already caused, or diagnoses and controls environmental problems.

A wider definition is proposed by Oltra and Saint Jean (2001), the authors include new elements such the respect of regulations, indeed they define it as the combinations of skills, knowledge, equipment and organizations required to achieve certain environmental objectives, comply with certain regulations. Markusson[5], proposes two ways according to which the concept of environmental innovation can be defined: first, by the effects of the innovation on the environment, and second, by the innovator's intentions to reduce the environmental impact of processes and products, the author introduces new element that is the intention of the innovator. Another research by Deprêt and Hamdouch[6], introduces the notion of “sustainable development” and put the emphasize on the effectiveness of environmental innovations compared to conventional technical solutions. Therefore, for the authors, environmental innovation is defined as a solution or a set of alternative solutions allowing more effectively than existing solutions to measure, monitor, limit, correct or even prevent damage to the environment and the climate or, more broadly, to respect the objectives of sustainable development”. Deshayes[7], proposes a definition which also emphasizes the preservation of the environment but which differs from the previous one, by adding a new element namely "organizational models”. Thus, the author defines environmental innovation as “products and systems allowing the reduction of energy consumption and limitation of the impact on the environment (GHG, CO2, etc.), organizational models, construction technologies and processes, equipment and materials themselves”.

Lastly for Farfan and Breyer[8], they propose their definition which focuses on a new concept “biodiversity”, for the authors, environmental innovation refers to innovative investment in biodiversity, in recycling and in environmental conservation programs. These different definitions already allow us to distinguish between two different categories of environmental innovations: the not purely technological environmental innovations and the pure technological environmental innovations. Indeed, many studies agreed on this point[6,9]. In this sense, what are the specificities of these two different types of environmental innovations? The first one designate innovative management and organization methods, routines, practices and services that the company must implement in order to integrate the environmental dimension at each stage of the life cycle (of its products / services / processes, or to make its employees, suppliers or customers aware of respect for the environment.

As for the second category, known as “pure technological environmental innovation”, this relates to new materials and systems, technologies or energies that reduce the negative effect on the environment. This category is in turn subdivided into two types: on the one hand, there are “end-of-pipe” technologies qualified as “additive”, they occur à posteriorisince they make it possible to reduce and limit the environmental consequences (eg: pollution control technologies, waste recycling, etc.). On the other hand, there are the so-called “integrated” technologies, which make it possible to prevent a priori (in advance) and reduce the production of pollutants by reducing the consumption of polluting inputs (green natural materials and resources) in the production process. In the following section, we present an illustrative case of the integration of environmental innovations in the building.
3. Results and Discussion

3.1 The integration of environmental innovations in the building

In this section, a case study is presented, it relates to the conceptualization / construction of a zero-energy building (Figure 1) as part of the international competition Solar Decathlon, Africa 2019. The building is designed with a circular shape that is inspired by the architectural model of traditional houses found in various African countries. The construction of this building is based on the use of an innovative material from the Moroccan hemp plant. It was developed by the cooperative AdrarNouh from the mixture of water, lime and the stalk of hemp. This material was used for the construction of the walls of the building. The exterior envelope of this building (double skin facade) was made of hemp panels with a natural resin. In addition to this innovative building material, there is a highly innovative photovoltaic panel system for the production of energy. This system adapts to the shape of the building (partially spherical shape).

![Figure 1. Zero-energy house](image)

During the usage phase, energy production covered the entire energy consumption of the building (TV, dishwasher, fan coil, electrical oven, computer, and lighting). For the production of domestic hot water, a solar thermal panel was more than sufficient. This building is considered to be a zero-energy building (it is a prototype building). In addition, hempcrete has several advantages with respect to environmental impacts compared to usual materials (conventional such as reinforced concrete and bricks).

3.2 Economic barriers to environmental innovation in the housing sector in Morocco

From an economic perspective, environmental innovations require massive investments and colossal upstream funds to finance research and development programs which are at the core of innovation. In addition, the payback time for these innovations is generally long term. Consequently, an in-depth study of the overall cost of the building via a long-term global analysis of its life cycle is therefore necessary in order to measure and estimate the financial benefit of integrating innovative solutions into the building. In this sense, according to Hajare and Elwakil[10], one of the biggest obstacles is a lack of awareness and a fear of initial costs among contractors, homeowners, and clients.

In Morocco, the vast majority of construction companies in Morocco and the different stakeholders involved in the act of building do not adopt this approach of analyzing and estimating the overall cost. Moreover, while it is true that on the one hand, environmental innovations can lead to an increase in the performance of companies[11], notably through a reduction in the consumption of energy or materials[12], on the other hand, however, the cost of learning and experience remain high and therefore limits the development and dissemination of environmental innovations, especially the so-called radical ones.
Indeed according to Goktan and Miles [13], the “first movers” invest and take the risk while the “followers” benefit from the competitor’s achievements before committing more surely. This causes a delay in the adoption of environmental technologies. Along the same lines, Jalonen[14] underlines this technological uncertainty, emphasizing the very uncertain nature of innovation activity in the field of environment. Therefore, for many companies willing to implement this type of innovations, there is often a high level of hesitation and a lack of commitment from business leaders and managers to initiate change because of the risks involved. This is an uncertainty which is of an organizational nature: In fact, environmental innovation imposes, on the different stakeholders who adopt it, a modification of their mode of production and / or distribution, their internal (and / or external) organization, their routines, and even their strategy. In this perspective, Dube and al. [15] add that will require a different approach to infrastructure, made possible by change in cultural perceptions, decision making processes and taking into account trade-offs in current and future equity issues and distribution of risks and benefits.

In Morocco, the great majority of businesses are family-run, operating in the form of SMEs and VSEs with very small structures, with in the majority of cases the total absence of organizational charts and long-term strategy. These very small and medium-sized companies do not have the material and immaterial resources and do not adhere to the logic of research and development and perpetual improvement that brings innovations. In fact, Moroccan companies, target sectors with rapid gains and reduced risk such as real estate promotion and natural resource-based activities. On another note, the implementation and absorption of environmental innovations (when they exist) require the existence of highly qualified and specialized skills: senior executives-engineers / architects, qualified labor (specialized technicians), people responsible for the control and / or implementation of technologies. The scarcity of these qualified profiles in Morocco causes them to be expensive, which would translate into a lack of productivity and competitiveness for companies that decide to engage in environmentally responsible buildings.

Concerning the case study of the solar house that we presented in the second section, the cost of the hemp-curved panels and the solar panels together represented more than 50 % of the overall cost of the building. In Table 1, we present a comparative analysis based on two different scenarios: each one describes the use of a specific type of construction material for the envelope and a specific technology for the PV system: The first scenario is a “Basic/conventional solutions” scenario and the second one is about an “Innovative Solutions” scenario.

**Table 1.** Building cost (Envelope and PV system) according to two different types of materials and technologies (prices are in Moroccan DH)*

| Zero energy building cost (Envelope and PV System) | Innovative solution | Basic solution |
|-----------------------------------------------|---------------------|---------------|
| Local hemp concrete                           | 59272               | Local red brick 6 holes 43292 |
| Hemp curved panels                            | 375191              |               |
| PV system with storage                        | 353990              | Basic PV system with storage 302220 |
| Total                                         | 788453              | Total 345512 |

*1 DH = 0.89 US $*

As we can clearly see from the table above, the basic solutions are much cheaper than the innovative ones (50% less). This is partly explained by the fact that most innovative/environmental friendly solutions are imported from foreign countries. This is the case of the PV system and the Hemp curved panels that were used for the construction of our zero-energy house. The PV system with storage that was used is very sophisticated and there are no similar ones that are produced locally. With regard to the hempcrete, while it is true that it has many advantages on the thermal, acoustic...
comfort and on the environment, its price however, is relatively higher than that of the red bricks holes that are widely and commonly used in Morocco.

Also, hempcrete is until now not produced at a high scale and is not integrated in the industry (it is still produced manually), thus there are no gains from scale economies. This is indeed another economic barrier that made the zero net energy house expensive. In the same sense, the production process of hempcrete is labor intensive and takes more time than the process of producing conventional materials such as concrete, this systematically translate into an increase of the cost.

Another barrier that was faced is the transportation cost, in fact hemp is a bio-sourced material that is only available in the Rif Region, but the construction site was located in the Green Energy Park in Ben Guerrir located 700 kilometers away.

The cost differences between the materials as well as the technologies we compared have also many implications on the demand side. In fact, the potential demanders for environmental innovations in the building sector are uncertain and this is not only due to the cost issue but also to the economic and socio-cultural behavior of consumers (future inhabitants / potential residents/buyers) that is very unpredictable with regard to the acceptance of this type of solutions. Also, these kinds of innovations are still not affordable for everyone as its initial cost is high relatively to the purchasing power of households. A macro-level study by Frondel, Horbach and Renning[16] summarized the most important factors that shape companies decision when it comes to innovating in the field of environment: They demonstrated in their study that the decision to innovate in environmental solutions depends on the relative importance of five factors: - the economic motivations of the company; - the nature of the business and the structure of its market; - the nature of the company's environmental management tools; - the intensity and nature of the environmental policy instruments implemented; and finally the influence of the pressing groups and lobbyists.

In Morocco, it is difficult to aspire for the generalization of environmental innovations in the building sector because the transition will require a transformation of the linear model of production towards a circular model, there will certainly be winners and losers: Indeed, the conversion to new modes of designing/conceptualization and producing buildings is not easy and will not pass without resistance from several groups of lobbyists/pressure.

4. Conclusions

Finally, in this article, we discussed and analyzed the economic barriers of the integration of environmental innovations in buildings in Morocco by giving as an example the case of a zero net energy house. The literature on the subject distinguishes between two categories of environmental innovations: "environmental innovations that are not purely technological" (sustainable management, routines, practices, modes of organization of the company) and a second category "purely technological innovations"; These latter are subdivided into two types: the "integrated" technologies (which intervene upstream) and which have a preventive nature "Green inputs" and the "additive" technologies qualified as "end of pipe" or "at the end of the chain" since they intervene downstream to control and reduce the environmental impact. At the empirical level, to enrich our analysis, we were particularly interested in one example that concerns a purely technological environmental innovations, more specifically studying the use of an innovative/green material (hempcrete) and an innovative system (the curved solar photovoltaic panels) in the case study prototype zero energy house. The results of our analysis show that these alternative solutions reduce the carbon impact on the environment. However, the cost of these innovative technical solutions remains high relative to conventional solutions. For example, the square meter built of the solar house shown in our example is 1300 Dollars / m2. In addition, the payback time is usually very long and the initial investment cost is high. The uncertainty of companies accentuated by the reluctance of households may hinder the generalization or the trivialization of these alternative technical solutions.

References

[1] Ministère de l’Aménagement de Territoire (2020) de l’Urbanisme de l’Habitat et de la Politique de la ville, Tableau de Bord Du Secteur de l’Immobilier
[2] IEA (2020) World Energy Balances - Data Product

[3] Kemp R Smith K and Becher G (2000) in Physica, Heidelberg pp. 43–66

[4] Hemmelskamp (1997) J Eur. Plan. Stud. 5, 177

[5] Markusson N (2011) J. Clean. Prod. 19, 294

[6] Ennima, S. et Al. (2021) Intelligent system and optimal minimisation of energy consumption on the attitude control of a voltauavhexacopter based on fractional control laws, Journal of Theoretical and Applied Information Technology, this link is disabled, 99(12), pp. 2780–2791

[7] Deshayes P (2012) Innovations 37, 219

[8] Farfan J and Breyer C (2018) in Energy Procedia (Elsevier Ltd), pp. 403–411

[9] Patris C Rousseau A C Valenduc G and Warrant F (2001) L’innovation Technologique Au Service Du Développement Durable

[10] Hajare A and Elwakil E (2020) Sustain. Cities Soc. 61, 102293

[11] Zhang D Rong Z and Ji Q (2019) Resour. Conserv. Recycl. 144, 48

[12] Porter M E and Van Der Linde C (2017) in Corp. Environ. Responsib. (Taylor and Francis, 2017), pp. 61–82

[13] Goktan A B and Miles G (2011) Manag. Decis. MD 49, (2011)

[14] Jalonen H (2011) J. Manag. Res. 4, 12

[15] Dube O P Brondizio E S and Solecki W (2020) Curr. Opin. Environ. Sustain. 45, A1

[16] Frondel M Horbach J and Rennings K (2007) Bus. Strateg. Environ. 16, 571