Innovation management process in the biomass generation from microalgae

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Abstract: *The aim of this of this study is to examine the dimensions of innovation management to explain, from a strategic perspective, the process in the development of innovative projects applied to cultivation systems for the generation of algal biomass. The employed methodology incorporates dynamic change contexts, generating high uncertainty in organizational decision-making. Managing innovation in renewable energies implies a structured and systemic process that includes technological surveillance, competitive intelligence, foresight, and planning. The results show that technological surveillance offers the possibility of making progress on border knowledge in the design, manufacturing and instrumentation of photobioreactors for the microalgae culture. It is concluded that the costly process for the generation of renewable energies for human consumption leads to reflect on its viability before being available for use, especially the management of those actions aimed at creative solutions.*

Keywords: *Management, innovation process, generation of bioenergy, algal biomass*

Introduction

This document offers an analysis of the dimensions of the innovation management to explain, from a strategic perspective, the process in the development of projects related with the bioenergy generation from microalgal biomass. The current world paradigm of production and consumption of energy services, sustained by fossil fuels (petroleum, charcoal and gas) is responsible of the 78 percent of the total emission of anthropogenic greenhouse gases (GHG). Therefore, any strategy to supply energy services to cover basic requirements of lighting, ambience, mobility, communication, to ensure the production systems required by the modern society to guarantee the sustainable social and economic development, must take the key variables of the environmental impact in to account (Arvizu, et al., 2011). In this context, the renewable energy sources have gained relevance for its contribution to the new production and consumption configuration of energy services with a sustainable social and economic development approach. In this task, the competitive and technological surveillance around the development of new production technologies for algal biomass, offers the chance to go forward in the leading edge knowledge in the design, manufacturing and instrumentation of photobioreactors (PBR) for the microalgae culture. The technological plan based on these tasks defines the enabling strategy of the necessary resources and the procurement, assimilation, development and transfer of technologies. The described task is fundamental in order to gain knowledge, any time that in literature is recognized that the obtaining of algal biomass as source of energy is still a complex and expensive process. Consequently, it is still in the research and development phase before achieve socialization of the required renewable energy resources and technologies to face the world sustainability challenges. The results show that the integration of business strategies for the bioenergy generation from algal biomass following a structured and systemic process from a strategic perspective is needed. It is concluded that the expensive process of the renewable energies generation for the human consumption leads to reflect on the viability before make it available, specially the management of those actions orientated towards creative solutions. The remaining parts of the document are structured in one way that in the first section the theoretical considerations about the management need of open models for innovation and the collaborative networks building to face the actual challenges related with the energy consumption, where the renewable energies appears as one possible alternative, are exposed. In the second part the method employed is described. Finally, in the third section the results, conclusions and recommendations are exposed.

Theoretical considerations

The energy sources accessible to all humankind are diverse, but some of them are very expensive due to the manner in which are obtained, it takes several years before extraction and marketing. According to the economic efficiency principle, one production system is efficient when it achieves a given level of production with the minimum consumption of resources (Samuelson, 2010:13), in other words, it means to exploit the resources in an optimal way. The efficiency in productivity terms could be defined as the amount of product obtained in a given amount of time (McEachern, 2003:24). This relationship is converted in an indicator that reflects how well the resources of an economy are being used for the production of goods and services (Martínez, 2012:2). However, the productivity has to be translated necessarily in economic productivity, that is, the relationship between amount of production and the resources employed but measured in monetary terms. Therefore, the productive efficiency is achieved once that a given production value is reached with the minimum possible costs. One of the challenges for the attainment of many products in a competitive way, biofuels from microalgae included, is to achieve productive efficiency of the culture systems able to generate economies of scale, that is, they have to operate with minimum water and energy consumption but with maximum algal biomass production.

Management of open innovation models

Up until a few decades, leading companies worldwide kept knowledge monopolies (Chesbrough, 2003), but in a knowledge society (Drucker, 1993) the generation of new knowledge and its distribution surpassed the knowledge gained by the research and development centers. Today, it is easy to imagine that a big part of the knowledge is tacit and fragmented among big enterprises, clients, suppliers, universities, research centers, laboratories, industry consortia and small new enterprises. Therefore, to adopt a different vision concerning innovation process management to promote the search for knowledge and ideas, more outside than inside of the enterprise, is becoming a common practice adopted by a growing number of enterprises through the open innovation strategies, with the aim to provide a new impulse to their business. In fact, the management of open innovation models gives priority to the creation and application of business models that takes into consideration the intentional input and output knowledge flows to accelerate the internal innovation and to expand the external innovation markets (Chesbrough, Vanhaverbeke & West, 2006 as cited in Ribeiro & Silveira, 2015) creating innovation networks. That is, reinforcing the enterprise links with other organizations through relationship networks to improve the communication, the information exchange in a more precise manner, leading to sustained growing of the business. Because, according to Ribeiro & Silveira (2015), those enterprises participating in relationship networks will be more innovative that those that do not. In this way, constructing a networking structure, of collaborative relationships, without a doubt influences the potential to build knowledge and to provide more dissemination capability by means of the network, stimulating communication and cooperation through networking among partners (Schilling y Phelps, 2007).

The Organisation for Economic Co-operation and Development and the statistical office of the European Union defined innovation as '…the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations' (OCDE-OECE, 2005). Drucker (1985) conceives the innovation as a tool for the innovative entrepreneurs, it is the means by which the change can be exploited as an opportunity for a new business, it is the action to provide added economic value to products and services. Other authors have defined the innovation as the creative combination of knowledge, whose application should be useful, profitable, constructive or adequate to solve a problem or necessity (Solleiro & Herrera, 2008:18). These last authors argue that the innovation [technological innovation] allows enterprises to generate new and better products and, in the case of industry processes, cost reduction or quality improvement. More widely, the innovation is understood as a potential source of sustained competitive advantage for enterprises. In synthesis, the innovation is the commercial application of an idea, while the management innovation is responsible for organizing and directing resources and capabilities of the company in order to increase the creation, accumulation and shearing of new knowledge, idea generation that allows developing of new products, process and services or improve the existing ones. In that way, the innovation management process for algal biomass, contemplates a range of functions and activities to provide method to the development effort and the incorporation of new technologies oriented towards the cost reduction, increase quantity and quality of biomass through the PBR design improvement in order to increase the productive efficiency of microalgae culture systems.

Current state of renewable energies

Renewable energies are those obtained from inexhaustible natural sources and by their clean nature do not contribute to climate change. The Fourth Climate Change Report (2007) from IPCC concludes that the main part of the observed mean world temperature increase since middle of the 20th century, and very likely due to the increased anthropogenic greenhouse gasses, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbon (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF6). Since the fourth report, new evidence confirmed that the human influence on the climatic system is the leading cause of global warming, consequence of immediate emissions of CO2 coming from the combustion of fossil fuels and industry processes, and responsible for about 78 percent of the total increase of GHG emissions in recent years (IPCC, 2014).

In the search of new alternatives, the Intergovernmental Panel on Climate Change special report (IPCC, 2011) provides an analysis and detailed assessment of the new renewable energy technologies and their current function and reduction potential for the GHG reduction. The report also provides information about features and technical potential of various resources, the historical evolution of the technologies, their integration difficulties and social and environmental effects arising from its use, and a comparison of leveled costs of renewable energies and the more recent costs of nonrenewable energies. It shows the function of renewable energies on the pursuit of appropriate concentration levels of GHG and about the climatic change mitigation. The Intergovernmental Panel on Climate Change 2011 estimates that: (a) The renewable energies represents worldwide 12.9 percent of the total 492 EJ (1 EJ = 1018 joules = 23.88 million tons of equivalent petroleum) primary energy supply. (b) The most common used renewable energy was the biomass (10.2 percent), mainly traditional biomass for cooking and heating in developing countries, with a growing component modern biomass techniques use. (c) The hydroelectric energy represented 2.3 percent. (d) Other renewable energy sources (solar, oceanic, wind and geothermal) represented 0.4 percent. The report states that the renewable energies are becoming part of the technological revolution of the twenty-first century to decrease the economical petroleum dependency. All this inside an overwhelmed economy caused by the petroleum and gas scarce and increasing cost.

According to the International Energy Agency (IEA), the bioenergy is the energy obtained from any kind of biomass. The biomass is a biologic origin material (vegetal or animal) classified as traditional biomass and modern biomass. The traditional biomass from wood, vegetal charcoal and agriculture waste, commonly used by housing sector in developing countries for cooking and heating is generally unsustainable. On the other hand, the modern biomass can be classified in modern bioenergy (e.g. the electricity generation and combined generation of heat and electricity from biomass, from solid urban waste and biogas) and industrial bioenergy. The latter applied for steam heating, self-generated electricity, heating and electricity cogeneration for paper and pulp industry, forest products, food and related industries (Ottmar, Ramón, & Youba 2011: 163; IPCC, 2011).

Microalgae

In this context: Which is the actual potential of microalgae as fatty acid and lipids precursor to be converted or to generate biofuels? The growing interest on microalgae as unicellular organisms is due to their capability to produce an important amount of organic biomass from photosynthesis and mainly by CO_2 consume and light (Elrayies, 2018). Some microalgae varieties supply necessary proteins to human food and animal feeding, lipids and fatty acids (*triacylglycerols*) as precursors in the biofuels, pigments and pharmaceutical products generation (Slade & Bauen, 2013; Schenk, et al, 2008). The microalgae biomass provides a wide range of biotechnological products applied in food industry, health and medicine, feeding, organic compounds and biofuels (Hernández & Labbé, 2014). Because their high lipid content, 50 to 20 percent of dry weight (Santos, et al, 2016), there are interest in increase the production of specific lipids. In consequence, the large-scale production of microalgae could have important and varied environmental impacts, but the biofuel production sustainability is still in laboratory stage (Slade & Bauen, 2013:33). However, the diversity of microalga species is such that studies are underway on the variables relating to the productive efficiency (Slade & Bauen, 2013). The selection of microalgae species and the production technology. are related with the biomass end-use. This make sense if is taken account that the microalgae culture for biofuels is still a long way from a commercial reality due the high production systems cost. It is needed a special selection and maintenance of microalgae strains to achieve high vegetal oil content biomass and high productivity (Alam, 2012; Benemann, 2008). This is therefore an opportunity research and development area to explore and select algae verities and incorporate the appropriate technology in order to scale biomass production from described organisms.

Closed systems for microalgae culture

Considering the present state of the technology for PBRs, the central question is: Is it technically viable and feasible to obtain sufficient volume of biomass for commercialization? Against open systems, the closed ones allow the parameter control for the microalgae culture, make possible the production of mixed or monoculture hyperconcentrated cultures, offer the potential to increase productivity requiring an smaller footprint than the open ponds, enable sun light distribution in a wide surface, avoid water and CO_2 leakages, reduce the risk of contamination, enable continuous production and the total growing control of the culture (Slade & Bauen, 2013; Hernández & Labbé, 2014; Santos, et al, 2016). However, the closed systems tend to be more expensive than the open ones, their auxiliary energy consume could be grater, high initial investment is required and cleaning and maintenance costs are higher (Hernández & Labbé, 2014). Montesinos, et al (2017) concludes that the PBR design and development made to increase the productive efficiency of microalgal biomass, requires the multidisciplinary work to attend various related aspects. By instance, the cost-benefit analysis, physical layout, maintenance costs and energetic requirements. However, diverse private and public institutions, among them the Universidad Tecnológica de la Mixteca, are investing in design and develop innovative reactors to face the needs of scale-up, the product type to be obtained considering the geographic context (The Mixtec Region), and the kind of microalgae (e.g. Chlorella Vulgaris).

Method overview

The path followed was that defined by the national model of technology and innovation management (TIM). TIM functions and processes who integrate activities realized in a project or enterprise about the matter compose it. The model premises suggest that the TIM gives method to the technological development, distinctive technologies incorporation, and technological innovation efforts, done to create transform and to deliver value to clients; it is part of those organization management areas interested in technology as the spearhead of the competitively; finally complements the organizational effort carried out to add value. To this end, the next functions were developed: a) Technological surveillance (technological monitoring) by obtaining information about developing or patenting technologies related with design, manufacturing and PBRs instrumentation for algal biomass production (Aldasoro, Cantonnet & Cillerulo, 2012); b) Planning, including the development of a strategic frame who facilitate the selection of enabling action lines in the development of proposals oriented towards the creation of competitive advantages, such as the innovation plan review for the photobioreactor design (Drucker, 1993; Thompson, et al, 2003); c) Resource management, through research projects for the reinforcement of collegiate working groups (academic bodies) and full time professors; d) Protection, in order to protect and safeguard the innovated product, generally obtaining intellectual property titles; e) Finally, the project innovation implementation evaluating an improved product. In this case the product is an improved PBR.

Results and comments

Within the scope of the project of innovation management in renewable energy generation processes applied in the photobioreactor design, developed at the Universidad Tecnológica de la Mixteca by a collegiate group of researchers members of the Academic Group UTMIX-CA-37 part of the Industrial and Automotive Engineering Institute and Social Science and Humanities Institute, a set of organized activities are developed focused in the product improvement through the adaptation, development or integration of new technologies for biomass production from some selected microalgae species.

In order to monitor the technological environment four fundamental activities were realized: The research of project related to microalgae production at research centers, Higher Education Institutions (HEI) and domestic and foreign companies; the preparation of a list of domestic and foreign researchers and research institutes with work related to algal biomass production; preparation of a list of patents, and finally identifying design and instrumentation innovations in PBRs for microalgae culture. These activities allowed therefore to characterize different uses and applications for the microalgae and to build the actual state of the PBR's production (Table 1).

Technological surveillance dimension

Objectives	Goals	Actions
– Systematically analyze the production of scientific knowledge in relation to the culture systems for microalgae using photobioreactors	– Characterize the diverse microalgae applications. – Build the actual state of the photobioreactors production	– Research projects related to microalgae production conducted by Research Centers, HEI, companies or in collaboration among them – List researches and research centers that carry out work related to microalgae production in Mexico – List the patents related to photobioreactors – Identify innovations (product, process, marketing and organizational) who characterize the photobioreactors design and instrumentation

Table 1. Technological surveillance dimension to explain the projects development process related to generation of algal biomass bioenergy.
Source: Own preparation adopting the methodology proposed by the innovation and technology management model. Available at: www.fpnt.org.mx.

Table 2 shows the planning function employed to define eight action lines related with the research setting improved products and processes through the technologies development. The activities and procedures schedule was aimed to meet the established objectives and goals for the innovation project within the HEI context.

Planning dimension

Objectives	Goals	Actions
–Systematically analyze the production of scientific knowledge in relation to the culture systems for microalgae using photobioreactors	–Develop the technological plan. –Set the design parameters and instrumentations for the PBR. –Design and instrumentation for the PBR –Monitor the PBR variables	–Analyze key competences to identify potential sources of competitive advantages –Stablish design parameters for the photobioreactor and monitoring variables –Provide the product architecture –Manufacture and assemble –Test and commission –Measure the variables and analyze the statistical data

Table 2. Actions planning dimension.

Through the qualifying stage the technological infrastructure, technological competences of the staff, project management methods, developed suppliers, strategic alliances, tying arrangements, available financial resources, databases of procedures and learned lessons were examined (Table 3).

Resources activation dimension

Objectives	Goals	Actions
–Manage resources to finance the activities related with the product architecture definition, drawing constructive plans, modeling, manufacturing and assemble, test and commission, variables measurement and statistical data analysis	–Set the design parameters and instrumentations for the PBR –Design and instrumentation for the PBR. –Monitor the PBR variables	–Evaluate the technological infrastructure, technological competences, project management methods, alliances and collaboration agreements. –Participate in calls for innovation projects resources. –Human capital formation through the active participation of undergraduate and graduate students conducting thesis research, social service and professional practices

Table 3. Resources activation dimension for Project founding.

At the innovation product protection dimension, the protection strategy for the technological assets was stablished by the request of at least one patent in order to be prepared to exploit and license the innovation (Table 4).

Innovation product protection dimension

Objectives	Goals	Actions
–Protect the invention through patent application at the Mexican Institute of the Industrial Property (IMPI)	–Protect the invention	–Submit a patent application at IMPI in order to protect the technological heritage

Table 4. Innovation product protection dimension.

The project execution started with the state of the art review related to the innovation management aimed to know the existing situation concerned with technologies linked to the PBR use for microalgae culture. Finally, for the implementation dimension the products escalation will be needed employing processes related to the algal biomass production, organizational structures, business models and/or merchandizing methods (Table 5).

Implementation dimension

Objectives	Goals	Actions
–Develop the prototype	–Manufacture and test PBR prototype	–Design, manufacture, assemble, model and test of the prototype in algal biomass production

Table 5. Implementation dimensión

For the implementation dimension, progress was made with the PBR design manufacture and assembly. The product obtained named Undulated Flat Panel Photobioreactor is in testing stage. The design was focused to address part of the problems published in scientific literature related to walls biofouling and low mixing efficiency using thermoforming as the main manufacturing process. The design innovation was based in product development methods, industrial engineering tools as Quality Function Development (QFD), computational simulation and selections methods (Figure 1).

Figure 1. PBR prototype

Concluding remarks

To make progress towards the renewable energies sources and needed technologies come to be a reality and be able to face the world sustainability challenges management methodologies aimed to contribute to the innovation process as the here described are explored. Knowing in advance that the renewable energies benefits could contribute in the environmental impact diminishing and the sustainable development impulse to such an extent that its exploitation should be part in the sustainable development strategy and the backbone of all public policies. However, the migration towards the use of renewable energies is a process that, due to its complex nature, is at an early stage of research and development, in escalation tests, in feasibility analysis and operation costs, but overall, in the face of a restrictive market structure that is about to reveal its true potential, because its real development is tie to the current available technologies. We wish to emphasize that the development of the whole innovation project related to the renewable energies should arise from a careful analysis of key elements to provide the necessary support to the organizational decision making process in uncertainty contexts. The case explored here has to do with the innovation management process for the renewable energies generation from algal biomass.

Preliminary results show the need to integrate the innovation management into the business strategies for the renewable energy generation from algal biomass following a structured and systemic process from a strategic perspective. Accordingly, the innovation management of the renewable energies has to do with the act capacity over the key dimensions of different systems and processes, modifying its states and paths (Albomaz & Fernández, 1997; Solleiro & Herrera, 2008), must has a clear intention to generate, rescue, analyze, mature and take advantage of those divergent ideas that could be innovations and obtain a favorable competitive margin in favor of the actors involved (Damanpour & Wischnevsky; Ortiz & Pedroza, 2006). For the proposes of this paper, innovation management is understood as the process comprised of functions and activities that provides method to the efforts of introduction of new technologies in industrial process leading to a lowering of the cost, at the same time as increasing the renewable energies generation quality through the PBR design improvements for microalgae culture, creating key potential competences that become into competitive advantages. The costly process for the generation of renewable energies for human consumption leads to reflect on its viability before being available for use, especially the management of those actions aimed at creative solutions. The current world paradigm of production and consume of energetic services, sustained by fossil fuels (petroleum, charcoal and gas) demands that any strategy to supply energy services to cover basic requirements of lighting, ambience, mobility, communication, to ensure the production systems required by the modern society to guarantee the sustainable social and economic development, must take the key variables of the environmental impact in to account (Arvizu, et al., 2011). In this context, the renewable energy sources have gained relevance for its contribution to the new production and consumption configuration of energy services with a sustainable social and economic development approach.

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