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Catalvalor - A catalyst for change: turning a research project into business

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Abstract

The CATALVALOR project roadmap is an example of how a research project in the area of Chemical Science and Engineering, developed inside the academy, could be transformed into a business project and later in a start-up, step-by-step and with the commitment of all team members. In order to solve the problem of biodiesel production a sustainable solution was developed, including a disruptive technology based on a reusable solid catalyst that allows the use of all type of feedstocks in a simplified industrial chemical process, consequently decreasing the biodiesel operation production costs and making biodiesel an alternative fuel to the petroleum-based fuel. Here we present the roadmap of CATALVALOR project: a) from the problem to solution; b) from the research solution to the business idea, towards c) the start-up creation, the INNOVCAT Company.

Palavras chave: CATALVALOR, solid catalyst, biodiesel, entrepreneurship.

1. Introduction

The Chemical Industry and Energy sector are relying to a large extent on the relatively inexpensive and readily available petroleum-based carbon feedstocks. However, the energy demand estimated to increase over 60% by 2030, the crude oil price oscillations, the climate changes associated with the greenhouse effect and the decreasing fossil fuel reserves is persuading the switch to a bio-based Economy to replace the petrol-based industry in which society have depended on upon for the past 70+ years.

Biodiesel is a clean burning biodegradable and renewable fuel which can be used as a replacement to the conventional petroleum diesel. Biodiesel benefits are it is bio-degradable, non-toxic, negligible sulphur content and 60% less carbon dioxide emission. (Datta, 2016)

In fact, in recent years there is a clear tendency towards using this green fuel (Tabatabaei, 2015) due to the high crude oil prices which make biodiesel a viable alternative to petrol diesel. In fact, world biofuels production is expected to grow at an average of nearly 4 % per year until 2030, in spite of the impact of economic recession in some countries on biofuels development (Energy Information Administration, 2011). In particular, the European Union Renewable Energy Directive set the target of 20 % renewable energy by 2020, based on concerns to reduce greenhouse gas (GHG) emissions levels, as well as Europe's energy import dependence (European Commission , 2013). This boosts biodiesel as part of the solution to the energy and economic problems (Abbaszaadeh, 2012; Shahir, 2015). It is worthy to note that biodiesel is considered the fastest growing industry worldwide (Lam, 2010; Luque, 2010). The biodiesel market is projected to reach USD 41.18 Billion by 2021, at a CAGR of 3.8% from 2016 to 2021. Biodiesel products find usage in several end-use industries such as, automotive, power generation, marine, railway, agriculture, and mining in applications, including fuel, power generation, industrial solvent, and lubricating agent. The increasing usage of biodiesel across these industries is expected to drive the market for the biodiesel in near future. Nonetheless, the central policy of biodiesel to replace petro-diesel is yet to be achieved. So far, high production costs have prevented biodiesel from being competitive with diesel fuels in the absence of government incentives.

Of the various factors that contribute to the cost of biodiesel, feedstock is considered to be the most important. In addition to accounting for about 75–90% of the total operating costs, (Demirbas, 2009) its origin is directly related with its sustainability. In fact, although biodiesel is generally regarded as a viable "green" fuel that reduces noxious exhaust emissions, (Demirbas, 2009; Shahir, 2015) biofuel demand can impact on the global agricultural market and food prices. The feedstocks typically used in the production of first generation biodiesel are also edible substances (mainly refined oils) and consequently the interest of these different markets (food and biofuels) for the same feedstock has generated a competition creating economic and social problems increasing significantly their prices. The continuing controversy of food vs. energy has been an obstacle to wider public acceptance of biodiesel. This has led to the cultivation of crops that grow on land that is not adequate for, and does not compete with land used for food production, and to the use of waste fats and oils (Adewale, 2015; Bankovic-Ilie, 2014; Jaiyen, 2015; Pires, 2014). Consequently, employing wastes and nonedible oils in biodiesel production would eliminate the competition with food consumption and it will also allow for compliance with ecological and ethical requirements for biofuel.

Biodiesel is commonly produced by a chemical reaction (transesterification) between triglycerides (the main components of vegetable oils or animal fats) and methanol in the presence of a catalyst to improve the reaction rate (Meher, 2006).

One effective approach to decrease the biodiesel production costs is the substitution of the currently used feedstocks, by low cost and low-grade feedstocks (fats and oil residues). Nevertheless, the use of these low-grade feedstocks is still a problem for the conventional technologies (that uses toxic chemicals as homogeneous catalysts) because it requires pre-treatments of the feedstocks and post-purification steps of the produced biodiesel which increases even more the overall process costs. Employing waste and non-edible raw materials is mandatory to comply with the ecological and ethical requirements for biofuels. So, it is time to find new efficient processes meet the requirements of biodiesel manufacturing, (Anuar, 2016) in which the use of solid (heterogeneous) catalysts (Lee, 2015; Sani, 2014) is specially wanted in order to suppress the costly chemical processing steps and waste treatment.

Since 2010 we have been developing research work in REQUIMTE/LAQV research centre in the Chemistry and Biochemistry Department of Faculty of Sciences of University of Porto in the area of Environmental Catalysis by developing solid catalysts for biomass transformation into bioproducts and biofuels. During this time, we have been able to prepare novel highly active, selective and reusable solids catalysts for esterification/ transesterification of vegetable oils, animal fats and greases into their methyl esters, the components of biodiesel.

2. Turning a research project into a business idea

2.1- From the problem to solution

Biodiesel is a liquid fuel alternative to the petroleum diesel, but it is not widely used because of its complicated production process and high associated costs, which effectively is the major obstacle in the commercialization of biodiesel, in comparison to petroleum-based diesel fuel, Figure 1. The feedstock costs (typically refined feedstocks: refined edible oils) may represent up to 81 % and catalyst 2% in the cost structure of the raw-materials which represent up to 90% of the overall cost structure of biodiesel production, Figure 1. The fact that biodiesel and feedstocks (refined edible oils) have their prices set in international markets, limits the margins for the biodiesel producers. Thus, the economics of biodiesel production can only be changed through the development of cost-effective process technology including the development of new efficient solid catalysts and use of low cost alternative feedstocks.

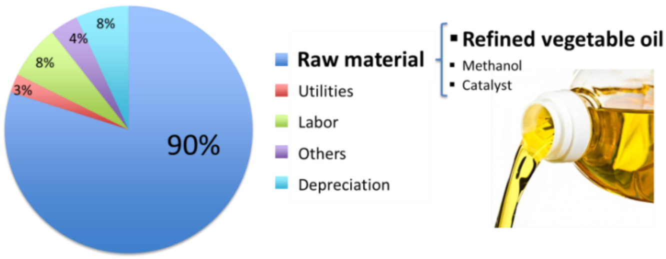


Figure 1: Biodiesel production costs

The introduction of low grade feedstocks is a huge problem for the conventional technologies due to the process complexity and maintenance increasing even more the overall process costs.

The actual biodiesel production processes are dominated by homogeneous catalytic processes due to the basic convention and less time required for the conversion of oils to their respective methyl esters (FAMEs, biodiesel). The sodium and potassium hydroxides (NaOH and KOH) are mainly used as basic catalysts because they are easily soluble in methanol, forming sodium and potassium methoxides respectively, enhancing transesterification reactions rate. When the free fatty acid (FFA) content of the oil is high, an acid catalyst (hydrochloric acid or sulfuric acid) must be used to reduce the acidity. To remove the added acid/base, the biodiesel must undergo a purification procedure which generates a huge amount of waste water.

The implementation or adaptation of the conventional processes by heterogeneous catalytic processes offers substantial savings in equipment, energy and materials by suppression of some operations and generation of less amount of wastewater, which leads to a significant reduction of the overall process costs with excellent economic benefits for biodiesel production, Figure 2.

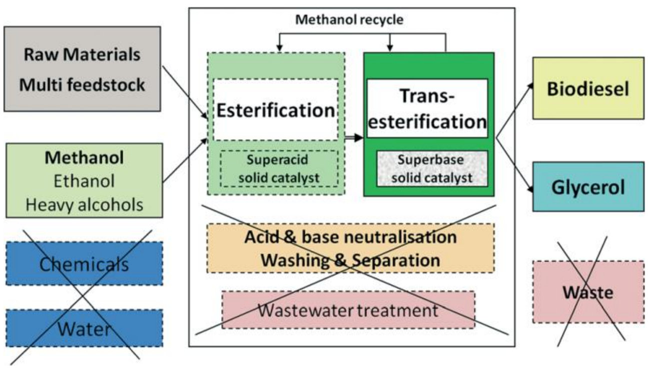


Figure 2: The advantage of biodiesel manufacturing by a heterogeneous base catalyst. Adapted from *Catal. Sci. Technol.*, 2016, 6, 6097–6108. (Dimian, 2016)

In the context of our research work on heterogeneous catalysis for biomass valorization we have been developing novel highly active, selective and reusable solids catalysts for simultaneous esterification/ transesterification of vegetable oils, animal fats and greases for methyl esters production, the components of biodiesel.

CATALVALOR project is a sustainable solution to solve the problems of biodiesel offering a disruptive technology based on a reusable solid catalyst that allows the use of all type feedstocks including low-grade fats/oils in a simplified chemical process, consequently decreasing the biodiesel operation production costs. This new catalyst has excellent adaptability to low grade unrefined feedstock and no waste water is created during the production process. In addition, it operates at significantly lower temperatures (60-120 ºC) and pressures (1-10 bar) due to its high catalytic activity, which can reduce cost and energy consumption. With our solution we can contribute to the increase of the global environmental impact of the biodiesel as the main environmental alternative to the diesel fossil fuels and since we enable the production of biodiesel from non-edible oils and waste (oils and fats) and we will also contribute to reducing the social and economic impact of biodiesel in the agricultural market and food prices. The technology was tested in academic environment at laboratory scale using pure and real feedstocks.

2.2- From the research solution to the business idea

Conscious of the importance of these scientific results in the context of XXI century Society Challenges and their potential for economic valorisation, we decided to submit the project to an assessment of its potential of commercialization and to learn how to transform the academic project into a potential business project; it is important to highlight the word *potential*, since not all academic projects can be transformed into business projects or ideas.

In 2013 CATALVALOR project was submitted to COHiTEC –*turning science into business*, a training program in technology commercialization aimed at supporting the valorization of the knowledge produced at Portuguese R&D institutions, sponsored by COTEC Portugal in partnership with the Porto Business School and with the north-American universities of North Carolina State, Brown and Rutgers. (https://www.actbycotec.com/en/cohitec.127.html)

This program, as other similar programs, is very useful for researchers who have never had contact with the basics of management and entrepreneurship for assessing the commercial viability of products or services that can be obtained from their science/technology proposals. During 3-4 months, the program give the tools to assess the viability of the projects in terms of team management, product idea generation, intellectual property, legal issues, financials, business models and business plan development, very important skills to move towards science to business inducing entrepreneurial and technology commercialization skills in the participants.

In the beginning, we were completely focused on the scientific aspects of CATALVALOR project, but soon realized that important aspects, such as market, uniqueness, need for the product or service, surpassed the scientific content. Consequently, during the program the research project was step by step, slowly turned into a business project, *CATALVALOR– a catalyst for change*: a solid catalyst, X-CAT, and a disruptive technology for efficient low-cost biodiesel production, Figure 3.

X-CAT allows the biodiesel producers to decrease the production costs by:

i) using low-grade feedstocks, allowing a significant reduction in the feedstock costs component (up to 50 %, Table 1) in the feedstock and biodiesel cost structures, following up the Directive

2009/28/EC of the European Parliament and of the Council of the European Union of 23 April 2009. The change of the high-grade (refined oils) to low-grade feedstocks represents a significant reduction in the OPEX higher than 20% enabling biodiesel to compete with petroleum based diesel on a cost basis, Figure 3.

ii) Simplified process allowing the reduction of >30 % CAPEX: simplification of the overall conventional processes due to removal of the pre- and post-purification steps and formation of large quantities of wastewater associated with the use of toxic corrosive liquid catalysts, Figure 3. Furthermore, there is no need of high-quality stainless steel due to non-corrosive and non-toxic properties of our solid catalyst and there is a significant reduction in costs of maintenance.

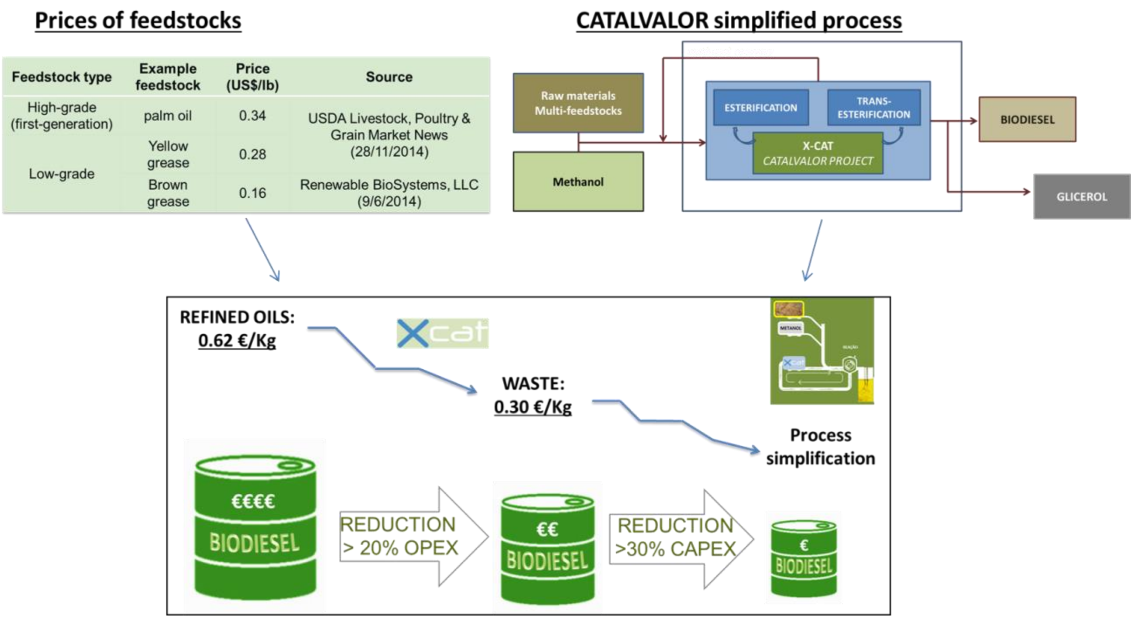


Figure 3: OPEX and CAPEX reductions on the biodiesel costs for CATALVALOR solution.

In summary, **CATALVALOR** project combines a solid catalyst (X-CAT) & Technology that allows biodiesel production from low-grade feedstocks (fats and oil residues), solving the main problems of biodiesel production especially their lack of competitiveness over the petroleum based fuels, since it reduces significantly the OPEX and CAPEX, by combination of a simpler industrial process with a renewable, reusable catalyst with high performance for low cost, low grade feedstocks (high FFA content) and avoiding feedstocks pre-treatment. In Figure 4 are presented CATALVALOR value proposition and a pictogram of our disruptive technology.

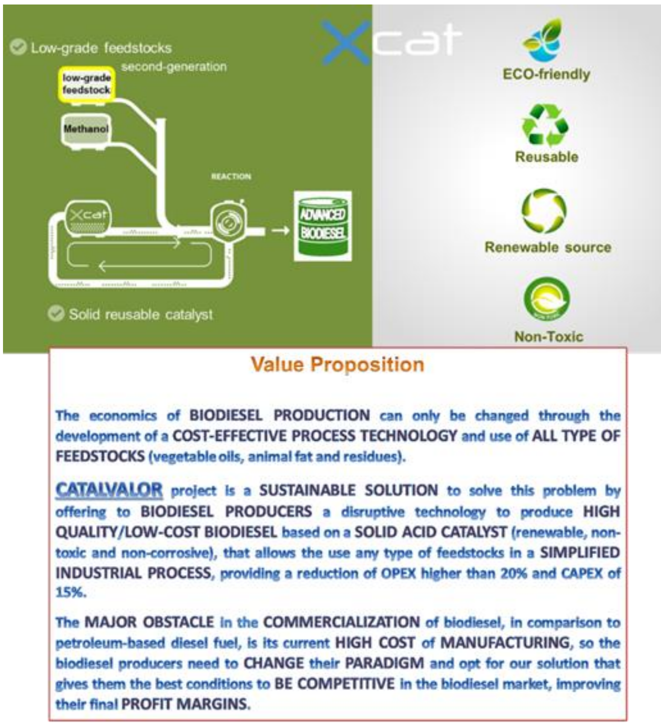


Figure 4: CATALVALOR Value proposition

The business model is presented in Figure 5, as a Business Model Canvas:

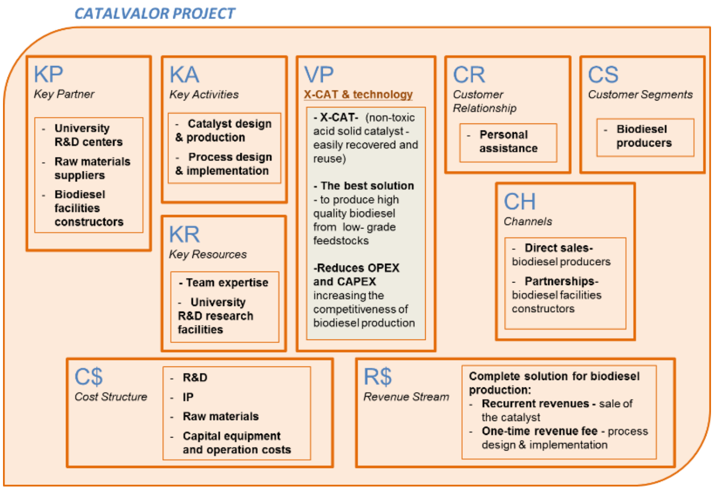


Figure 5: CATALVALOR Business Model Canvas

2.3- Towards start-up creation

With the support of COHiTEC, CATALVALOR researcher promoters realized the potential of generating economic value and competitiveness for industrial problem resolution; moreover, within the program we learned how to disseminate/present the project to national and international investors. Consequently, after COHiTEC program the project **CATALVALOR** continued with the technical and mentoring support of Act by COTEC to find investors and industrial partners for the business project.

CATALVALOR was the winner in the most important national entrepreneurship competition in Portugal, ***Acredita Portugal 2015***, in the category *Industry,* distinguished among more than 18 000 candidates in this edition, Figure 6. Inserted in this entrepreneurship competition, the CATALVALOR project was also one of the three finalists in *Brisa Mobilidade* award. In the same year CATALVALOR was also one of the ten finalist projects in iUP25k award, from University of Porto Innovation, University of Porto, Portugal.

Figure 6: CATALVALOR project winner of, ***Acredita Portugal 2015***

To provide the continuity of CATALVALOR project, in March 2015 the promotors of CATALVALOR project, Andreia Peixoto and Cristina Freire, created the INNOVCAT Company, currently branded as a *Spin-off of University of Porto*.

In December 2015, the company got a private investor - INCBIO, set its location in Maia, and it is now in the pre-industrial proof-of-concept stage of X-CAT production and technology testing, under the support of PT2020 funds- *Empreendedorismo Qualificado e Criativo em Setores de Alta e Média-alta Tecnologia* (2016).

After the approval from University of Porto on the patentability of CATALVALOR invention, we submit the invention to a Portuguese funding on Operational Program for competitiveness and internationalization – *Proteção da Propriedade Industrial – Projetos Individuais*" which has been funded for 3 years to obtain the National patent and the PCT (2016). The Portuguese Patent was deposited in March of 2017. The IP rights are in negotiation with the technology transfer office of the University of Porto, UP Innovation.

3. INNOVCAT Company

INNOVCAT is a technology-based start-up, which aims to carry out research & development, production and commercialization of solid catalysts and innovative functional materials for industrial applications in several areas.

INNOVCAT mission is to provide high-performance and cost-effective functional materials and solid catalysts for a wide range of applications and to a wide customer base; it also includes the development of innovative eco-sustainable technologies to reduce costs to be competitive in the market, Figure 7.

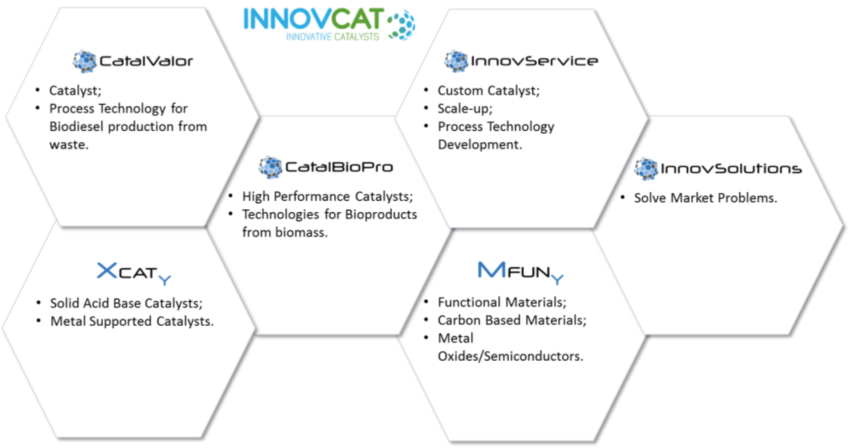
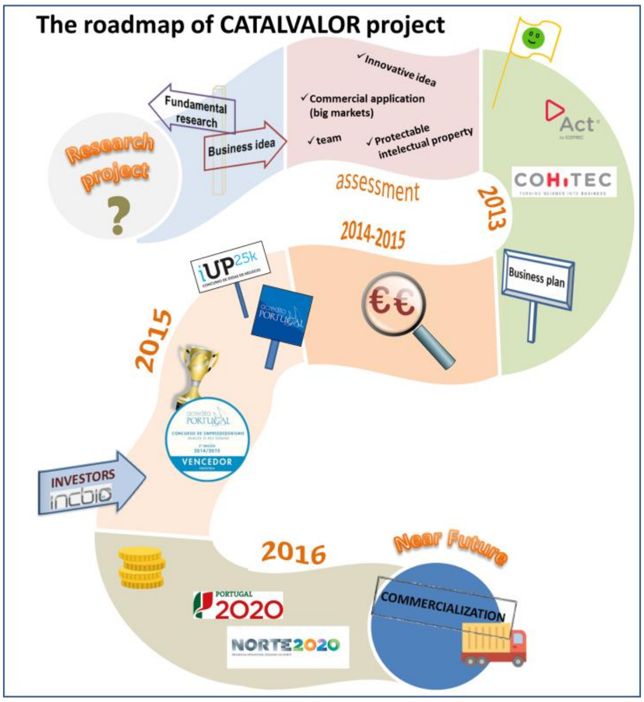


Figure **7:** INNOVCAT products, technologies and services.

4. Conclusion

The CATALVALOR project roadmap, from the research project to the business idea and to the company foundation, is an example of how a research project in the area of Chemical Science and Engineering, developed inside the academy, could be transformed into a business project and later, in a start-up, step-by-step and with the commitment of all team members.



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COTEC Portugal and UP Innovation and financial support from NORTE-02-0651-FEDER-019317 - *Empreendedorismo Qualificado e Criativo em em Setores de Alta e Média-alta Tecnologia* (2016) for catalyst pre-industrial production and commercialization.

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