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Conceiving, exploring, and exploiting innovative ideas: from waste cooking oil to diesel

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Abstract

Conceiving, exploring, and exploiting new ideas are the basis for technological creativity and innovation. By far, the most important step is the conception of a new idea having the potential to be transformed to a successful business solution. Nevertheless, the exploration of a new idea and its subsequent exploitation require both recourses and systematic planning in order to promote a sustainable entrepreneurship. An innovative idea of a new green technology for producing diesel from residual feedstocks was conceived and developed in the Centre for Research and Technology Hellas. The main concept of this technology is the innovative exploitation of waste cooking oil, which is abundant in Greece and other Mediterranean countries. The technology is based on catalytic hydrotreatment, a traditional petroleum process that is widely employed to upgrade petroleum products. The catalytic hydrotreatment of waste cooking oil was explored with the support of the European Program LIFE+, which funded both the research and development activities as well as the demonstration of the technology. A large quantity of waste cooking oil was collected and converted to the new diesel in a sufficient quantity to fuel a garbage truck for a few months, demonstrating the new technology. The new low-carbon technology offers a new diesel of increased sustainability, superior quality, better fuel consumption, and lower emissions. Furthermore, based on conservative estimations of the available waste cooking oil quantities in Greece and due to the high conversion yields of the proposed technology, it is estimated that waste cooking oil can satisfy approximately 9.5% of the national demand in diesel fuel. Due to all the aforementioned advantages, this technology was granted the second innovation award in the 'Greece Innovates' competition organized by Eurobank EFG and Hellenic Federation of Enterprises in July 2011. Towards the exploitation of this technology, the incorporation of waste cooking oil to an existing refining process is explored with the support of the European Commission and the Greek government via the project SustainDiesel. This joint project with the Hellenic Petroleum Group exhibits strong potential for getting scaled-up to industrial scale, thus promoting a green technology into the energy sector.

Keywords: Waste cooking oil, Hydroprocessing, Biofuels, Biodiesel

Background

The concept of *creativity* refers to the intention or creation or materialization of a new concept/idea/thing that has a certain value. Normally, creativity is associated with artwork and literary work and is linked with technology as well. A related concept is that of *innovation* which is mostly associated with technology and is referred to as the creation of better and more effective products, services, technologies, etc. Nevertheless, it is often difficult to put a boundary between the two concepts or to even associate a new product with either creativity or innovation. Both creativity and innovation, however, share the same three distinctive steps - conception, exploration, and exploitation of a new idea - in order to evolve and materialize an initial idea/concept into a higher added value result.

Methods

The first and by far the most important step towards creativity and innovation is the *conception* of a new idea. If there is no new idea, there cannot be any innovation or breakthrough. Furthermore, the idea has to be not only new/fresh but also useful. In order for an idea to be both fresh and useful, prior knowledge of problems that need to be solved as well as possible solutions is required. Even though there are no significant resources required for the conception of a new idea, this step contributes largely to the overall innovation/creation, as shown in Figure 1.

The second and very important step is the *exploration* of the idea. This step shows whether the original idea can or cannot 'work'. Unlike the first step of conceiving the idea, this second step requires significant effort and resources. An idea can be explored either by private funding (if it is a corporate-related idea) or by employing EU and/or national funding. In either case, the funding will provide the necessary resources (manpower, infrastructure, consumables, etc.) for exploring the idea further. The idea exploration includes research/studies related to the proof of concept, experimentation, scaling-up to industrial/commercial scale, techno-economic feasibility, etc. It is estimated that the exploration step is the second important step (Figure 1) in the overall innovation value from conceiving to materializing a new idea. Nevertheless, it should be noted that the more an idea is explored, the less the risks of failure during the third and last step of exploitation. Therefore, significant effort should be foreseen and dedicated in order to thoroughly explore the initial ideal.

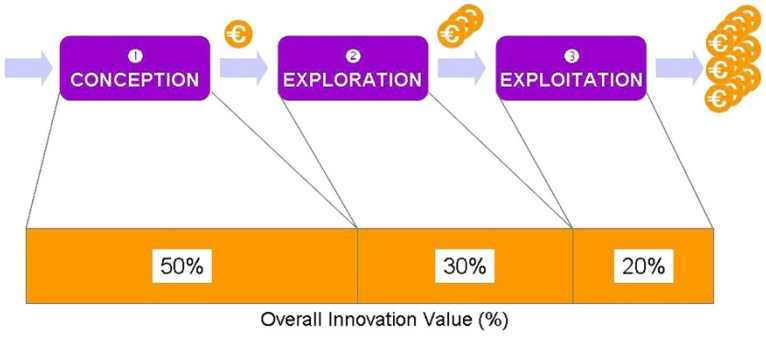

Figure 1 Conception, exploration, and exploitation steps and their corresponding contribution to the overall innovation value.

The third and last step towards innovation is the *exploitation* of the idea towards its implementation. The exploitation step will allow the materialization of the original idea into a successful business step, utilizing the findings of the exploration step. The idea exploitation ensures the competitiveness of the final product/service/technology. In order for the exploitation step to be successful, careful business planning as well as technology licensing and patents are required. Even though this last step is the most straightforward step and with potential to provide high profit margins, its value is the lowest as related to the overall innovation value, as shown in Figure 1, as compared to the preceding conception and exploration steps.

Results and discussions

The three steps towards innovation were applied for the research and development of a new technology for producing alternative fuels. The idea was conceived, explored, and exploited aiming to get commercialized and promote environmental and economic benefits. In the following paragraphs, these three steps are presented in detail as a case study for creativity and innovation, aiming to motivate young female researchers towards creativity and innovation.

Conceiving the idea

The exploration of alternative fuels was motivated by the two well-known worldwide problems of world oil reserve depletion and large contribution of transportation fuels to climate change. In fact, it has been estimated that transportation energy accounts for approximately 40% of CO_2 emissions (European Commission 2003). In Europe, as the diesel demand is continuously growing, the alternative diesel market which mostly consists of fatty acid methyl ester (FAME) biodiesel from plant oils grew rapidly (Knothe et al. 2005; Pahl 2005). Even though FAME biodiesel has shown potential for reducing the net carbon dioxide emissions, its commercialization is limited by the increased production cost of the raw material (i.e., vegetable oils) (Krawczyk 1996) as compared to fossil diesel.

The land competition between the energy-dedicated plants, i.e., energy crops, and the food crops has led to the increase of food market prices and the inevitable 'food versus fuel' debate. As a result, new alternative fuel technologies have emerged depending on residual biomass feedstock, including agricultural waste products (e.g., stems, leaves) and municipal wastes such as organic solids and waste cooking oils (WCO). In fact, WCO disposal is particularly problematic as 1 L of WCO could contaminate over one million liters of water, which is on average the amount of water that is utilized by one person for 14 years.

Interestingly, however, irrespectively of the source/type, biomass is generally not suitable for energy production. The oxygenated compounds (lipids, acids, ketones, etc.) contained in all biomass types induce oxidation, acidification, and even polymerization problems, while the water content gives corrosion problems to the resulting fuels' application. In order for the biomass to be converted to a suitable energy source, both oxygen and water should be removed.

Catalytic hydrotreatment is a key petroleum technology available in almost all refineries, as it is employed for product upgrading. As one of its targeted processes is the removal of unwanted heteroatoms (sulfur, nitrogen, metals), it was envisioned as a

possible process for removing oxygen. As a result, the idea emerged for evaluating the catalytic hydrotreatment as a potential technology for upgrading the WCO residual biomass feedstock into biofuels to remove oxygen compounds and water. However, as the catalytic hydrotreatment was never applied to WCO, the technology had to be explored in order to evaluate whether it is suitable for biofuel production.

Exploring the idea

The catalytic hydrotreatment of WCO technology was explored in the hydroprocessing pilot plants of the Laboratory of Environmental Fuels and Hydrocarbons of the Centre for Research and Technology Hellas (CERTH). As there was no prior literature/know-how on such technology, there were significant challenges that had to be faced.

Firstly, there was no hydrotreating catalyst specifically designed for WCO. In classical catalytic hydrotreatment applications, there are particular catalysts designed and developed to operate for different feedstock types, i.e., with different characteristics and for different process targets, for example, maximizing diesel yield, maximizing gasoline yield, or for isomerization. As a result, there was significant effort towards assessing commercial catalysts (Bezergianni et al. 2012) that could potentially be utilized for such application. After a series of dedicated experiments, the best hydrotreating catalyst was selected based on its effectiveness in maximizing diesel yield (desired product) while maintaining its quality. Secondly, the operating parameters of hydrotreating WCO (reaction temperature, pressure, liquid hourly space velocity, and hydrogen-to-WCO ratio) had to be optimized. A series of experiments were conducted in order to evaluate the optimal operating parameters that will maximize the desired product (biodiesel) yield (Bezergianni et al. 2010a,b, 2011).

The research experiments showed that catalytic hydrotreatment is an effective technology for converting WCO into diesel molecules. This is readily shown in Figure 2, where the WCO and hydrotreated WCO products are compared via their distillation curve, which in essence shows the size distribution of the contained molecules. The WCO molecules are too large/heavy to be used as diesel fuel. However, after hydrotreating, the product includes over 90% of molecules which are suitable for diesel fuel. This increased conversion also renders the catalytic hydrotreatment technology as a promising technology from an economic prospective as well.

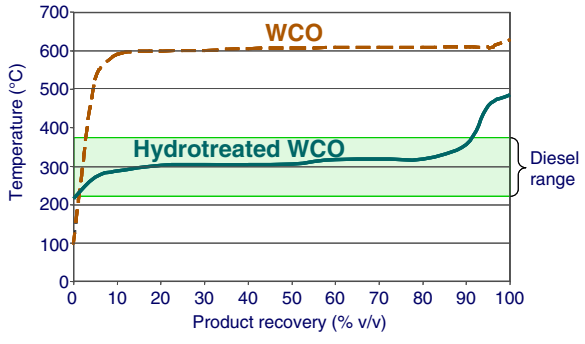

Figure 2 Comparison of distillation curve of WCO and hydrotreated WCO. The green band indicates the distillation range of diesel-like molecules (target).

Once this technology appeared as a promising alternative conversion pathway of a residual feedstock such as WCO into biodiesel, it was further explored in a larger scale, aiming to demonstrate its effectiveness. This was achieved via the BIOFUELS-2G project (Biofuels-2G project website 2010). This project involved the design, development, and demonstration of the new technology for the production of second-generation biodiesel utilizing 100% WCO. The project began on 1 January 2010 and had a total duration of 36 months. The project participants included the CERTH as a coordinator, the Aristotle University of Thessaloniki (AUTH), the Municipality of Thessaloniki, and the Association of Restaurant Owners of Thessaloniki. The total budget of the project was 1.4 million €, and it is co-funded by the LIFE+ Programme of the European Union by 50%.

The environmental nature of this project abided by its target to mitigate climate change and promote a new sustainable technology for the production of biofuels from waste. The environmental character of the technology was also enhanced by incorporating hydrogen which was produced by solar energy, i.e., solar hydrogen. It should be noted that this innovative technology was implemented for the first time worldwide in Thessaloniki/Greece through the demonstration of the new biodiesel production process and its use on municipal vehicles. The BIOFUELS-2G project promotes the use of second-generation biofuels, contributing to the reduction of carbon dioxide (CO_2) emissions from transport and the exploitation of waste cooking oil in the city of Thessaloniki.

In order for this demonstration project to be completed, several actions had to take place as schematically depicted in Figure 3. All main demonstration activities were performed in the following four phases:

a. *Development of a network for waste cooking oil collection by the Municipality of Thessaloniki and the Association of Restaurant Owners of Thessaloniki*. Twenty three (23) restaurants located all over Thessaloniki participated in the WCO collection program, in order to collect 3 to 3.5 tons of WCO. The participating restaurants also acted as collection points for WCO that could be disposed by the public. The WCO collection from the 23 restaurants was performed using a specially converted semi-truck of the Municipality of Thessaloniki.

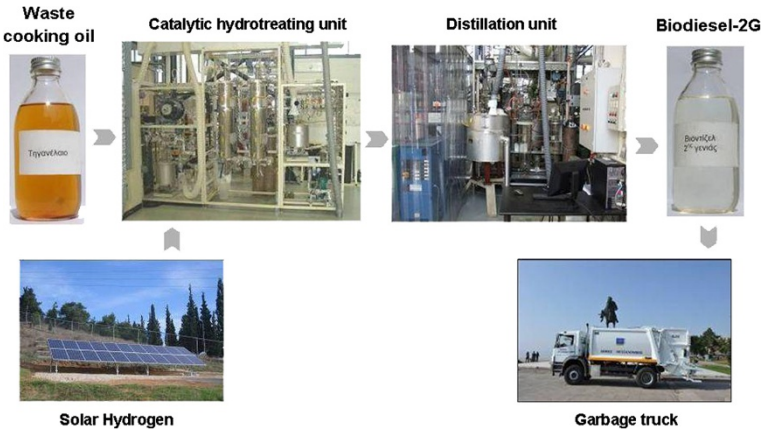

Figure 3 Demonstration project BIOFUELS-2G. Source: Biofuels-2G project website (2010).

b. *Production of second-generation biodiesel from WCO using solar hydrogen by CERTH*. The conversion of the WCO collected to second-generation biodiesel was performed in the large hyroprocessing pilot plant of CERTH, leading to the production of 2 tons of the new fuel. The sustainability of the overall production scheme was enhanced by utilizing solar hydrogen which was produced from a special unit which included photovoltaic panels and a custom-made electrolyzer.
c. *Testing of the second-generation biodiesel in engines by AUTH*. The new biodiesel was tested in engines and vehicles in order to evaluate the associated emissions, fuel consumption, and engine effects. The results were compared with those of conventional/market diesel fuels and showed that they were more favorable for some emissions, while they had no effect in the engine performance.
d. *Demo utilization of the new biodiesel in a designated garbage truck of the Municipality of Thessaloniki, while recording results and measurements*. The demonstration of the new fuel was initiated on 10 September 2012 (National innovation competition "Greek Innovates" website 2011).

In all the aforementioned activities, it should be noted that women's creativity played a leading role as the conception and exploration of the new idea were conceived by the hydroprocessing research group of CERTH led by a female researcher, Dr. Stella Bezergianni. This research group also consists of three research assistants, one female chemical engineer, one female chemist, and one male mechanical engineer.

Based on the results of this demonstration project of the new technology, several advantages are expected, including:

- Production of useful products such as environmentally friendly fuels (second-generation biofuels) from WCO
- Reduction of carbon dioxide (CO_2) emissions during the sustainable production of second-generation biofuels, especially when utilizing solar hydrogen
- Reduction of total wastes' volume by the collection of WCOs
- Potential to apply such technology in cities and in particular in dedicated fleets (buses, taxis, garbage trucks, etc.), reducing the emissions in an urban environment.

Figure 4 Technology dissemination and promotion activities.

Exploiting the idea

In order to promote this idea, the CERTH hydroprocessing research team entered a national innovation competition 'Greece Innovates' (2011) and won the second prize. This nomination proved to be a great promotion of this technology as it was advertised via all national broadcasting media (TV, radio, newspapers, magazines, e-news, etc.). The technology was presented in articles in over 16 newspapers and over 130 websites, 4 interviews on TV, and 15 interviews on radio. Moreover, the technology was also promoted via 15 presentations in national and international conferences, 15 general presentations, and 8 technical publications in renowned scientific journals. The extent of the dissemination of this new technology (Figure 4) was effective as it raised the interest of investors inside or outside Greece

Furthermore, the innovative technology is currently exploited via the collaboration with the private sector. In particular, CERTH is working with the Greek Oil Company Hellenic Petroleum to explore the feasibility of integrating WCO in an existing refinery. This project called SustainDiesel is currently partially funded by NSRF 2007-2013 and particularly by the research programme SYNERGASIA for a total duration of 36 months and is expected to be completed by March 2014.

Conclusions

A new innovative technology was developed for producing alternative diesel from waste cooking oil. This innovative idea emerged via the hydroprocessing research group of CERTH in Thessaloniki, Greece. The idea was further explored in order to test its technical and practical feasibility and ability to be scaled-up in industrial scale. The exploration was performed by research programs funded by the EU. The technology was later exploited via participation in innovation competition, promotion in national and international conferences, and also collaboration with the private sector.

The contribution of female creativity on this technological achievement is significant as the hydroprocessing research group is led by a female engineer, while it also consists of a majority of female research assistants.

Competing interests

The author declares that she has no competing interests.

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