Review a Decade of BP’s Technology Roadmap on the Next Generation Biofuels Development

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Abstract. Philip New—the ex-CEO of BP Biofuels proclaimed in 2007: the emergence of biofuels involves two value chains—agriculture and energy, where both mature industries are connected to new national/regional policy. This has opened various opportunities for developing countries to tie business relationships through BP’s investment into non-food next-generation biofuels (NGB) feedstocks farming. This study reviewed all BP’s NGB development projects undertaken from 2006 until 2016. Secondary data was collected through media, corporate websites/reports and newsletters. Next, the NGB development projects were mapped into a technology roadmap (TRM). From this case study, it is hoped that BP’s pursuance on the NGB development could be referred by other oil companies that would have a similar intention of the NGB developers.

Keywords: the next generation biofuels (NGB) development, technology roadmap (TRM)

1. Introduction

BP is currently embarking on the progress of NGB development. Founded in 1908, BP has been supplying fossil energy products worldwide for more than a century. Thus, biofuel is a new business profile. Operating in more than 100 countries, BP’s expertise covers three areas: exploration and production; refining and marketing; alternative energy introduction and development—where biofuels businesses are located. This study reviewed all BP’s NGB development projects undertaken from 2006 until 2016.

2. Literature Review

2.1 Technology Acquisition

Technology acquisition aims to enhance its technological/technical capability (Ziedonis, 2004; Poon and MacPherson, 2005; Hung and Tang, 2008). Apart from the economies of scale (Hagedoorn and Duysters, 2002; Desyllas and Hughes, 2010), technology acquisition increases organisational capability to develop knowledge (Cohen and Levinthal, 1990). This helps the organisation’s near-term achievement (Cloodt et al., 2006; Makri et al. 2010) and long-term competitive advantage. According to Khalil (2000), there are five routes of technology acquisition:
(a) Internal R&D: The firm depends on internal human resources to develop the technology. This requires the presence of a strong workforce, infrastructure and financial for R&D operations.

(b) Buying Technology: This is the fastest way to obtain technology. It does not involve many resources, apart from financial which backs the technology purchase. However, the buyer does not have full control of the technology purchased.

(c) Licensing: This depends on the type of contract and intellectual property rights of the technology. Through this method, a company purchases the right to utilise the technology (owned by someone).

(d) Joint-venture: This occurs in complex and huge projects which need high budgets, human-technical resources and interdisciplinary approaches. The joint research effort is one good example since two/more firms combine their know-how and technological resources to develop new technology, while risks and benefits are shared.

(e) Contracting out for R&D: By contracting out, a company can conduct R&D without having to invest heavily in an in-house R&D on its human capital and technical infrastructure. This is welcomed since many companies are gradually reducing the expenditure. On the other hand, the laboratories have the necessary human-technical resources by making their service available commercially. University-Industry Collaborations put the university R&D capacity with the industry support for R&D process.

2.2 Technology Roadmap
Phaal et al. (2004) explain, technology roadmap (TRM) is used to set-up strategic planning. Galvin (1998) adds, a TRM will provide a foresen in the future. Generally, TRM is widely used in technology management (Phaal et al., 2004; Rinne, 2004; Lee and Park, 2005), with graphics to explore relationships among markets, technologies and business approach (Albright and Kappel, 2003; Lee and Park, 2005).

2.2.1 Developing the Technology Roadmap. EIRMA (1997) explains, there are three approaches to build a TRM. The first is ‘time’ which presents the current and future situations. The second is ‘expected achievement’ with the projection associated with external influences. The third is the ‘interrelationship of technologies’ that support the identification of R&D for near-future execution. The fourth is the ‘identification’ for an R&D program; while lastly, the ‘identification’ of the human resources.

3. Research Methods
This study has begun since September 2006 till December 2016 where the secondary data was collected through media, corporate websites/reports and newsletters. It was a mass volume (a decade) of secondary data reviewed through thematic analysis. Saunders et al., (2017) explain, the essential purpose of the thematic analysis is to search for themes/patterns that occur across a data set. Thematic analysis procedure, in practice, does not occur in a simple linear progression. Instead, it often concurrent and recursive, involving when the researchers are analysing data as collected the data and going back over earlier data and analysis as to refine the way in which have been coded and categorised newly collected data and search for analytical themes. The procedures outlined here involve: becoming familiar with the data; coding data; searching for themes and recognising relationships; refining themes and testing propositions (Chew, 2017), which is suitable for this study for review a decade of BP NGB development. Finally, all of the NGB development projects were mapped as a decade of BP Biofuels TRM.

4. Results
4.1 BP Embarking on the Next Generation Biofuels (NGB) Development

There are three objectives which leading BP to embark on the NGB development (BP, 2009a) (i) to produce biofuels from the most efficient feedstocks available, (ii) to search for new feedstocks, (iii) to develop advanced biofuels. As such, BP invests in the NGB R&D projects that can achieve significant GHG reduction; safeguard energy security; and offer commercial opportunities for the agriculture industry in growing biofuels feedstocks (BP, 2009b). Since from the year 2006 to 2016, through few Joint-Ventures and Contracting Out, BP has established fourteen NGB R&D projects which spread across the world. These projects set ways: (a) to increase the productivity of biofuels supply for the aim of economies of scale; (b) to switch biofuels away from the food chain; (c) to overcome the limitations of the 1G biofuels; (d) to emphasise the green and sustainability criteria and comply with regulations (BP, 2009c).

4.1.1 Project 1: BP and The Energy and Resources Institute (TERI) India, 2006. This project is to demonstrate the feasibility of producing biodiesel from Jatropha curcas-an a crop which is drought resistant and grows on marginal land. BP is funding a USD9.4 million on Jatropha project, implemented by TERI at Andhar Pradesh. TERI is responsible for the management/execution of the project: from farming to biodiesel production. (MIT Technology Review, 2009). The project is expected to take 10 years, will cultivate 80km² of jatropha on wasteland. Besides, the project could produce approximately 9 million litres of biodiesel per annum (BP, 2006a). The latest update in 2009: the project is funded by TATA BP Solar Limited (TERI 2009).

4.1.2 Project 2: BP and DuPont formed a JV company-Butamax Advanced Biofuels, 2006. This project is to explore new product at biofuels development that would perform better than bioethanol. The first product is biobutanol. It has higher energy content, provides better engine performance and could enhance fuel efficiency. The construction of a biobutanol demonstration plant in Hull, the UK is completed, by using processed cereal feedstocks (BP, 2006b). The pilot plant produces 20,000 litres of biobutanol per year, which can be blended into petrol at various concentrations. This plant has begun its production at the end of 2010 (BP, 2009d; Semans and de Fontaine, 2009). In 2013, Butamax is launched through a commercial production biobutanol plant in the US (Butamax, 2016). In 2016 with the intention of bio-isobutanol commercialisation, BP has acquired an ethanol facility in Kansas (BP, 2017a).

4.1.3 Project 3: BP and Energy Biosciences Institute (EBI), 2007. This project focuses on the NGB development from biology applications into energy. EBI is a collaboration between three American universities-the University of California Berkeley, the Lawrence Berkeley National Laboratory and the University of Illinois that conducting research activities, while BP supports the institute financially with a ten-year USD500 million grants (EBI, 2006, 2008, 2016). BP will venture on the learning curve to acquire know-how in strengthening its institutional knowledge of bioscience/biotechnology (Knott, 2007). Hence the expertise, experiences, track records and reputations of these three American universities have convinced BP to fund in and get the institute established.

4.1.4 Project 4: BP and Mendel Biotechnology, 2007. This project develops high yielding energy grasses such as miscanthus, elephant grass, switchgrass and sorghum as potential biofuel sources. In June 2007, BP collaborates with Mendel Biotechnology (Mendel, 2008). BP is funding this five-year research programme. Mendel has experience in establishing breeding programmes of perennial grass for various improvements. As such, Mendel plans to advance this project by setting-up stations around the Midwest/South East of USA, as well as by promoting further cooperation with agriculture research groups in Germany and China (BP, 2007a). In 2012, Mendel Biotechnology Inc., together with its owned subsidiary-Mendel Bioenergy Seeds, and BP Biofuels have signed a four-year agreement to
conduct a demonstration field trial of Mendel’s trademarked PowerCane Miscanthus (Sims, 2012; Sapp, 2012).

4.1.5 Project 5: BP, British Sugar and DuPont, 2007. This project is to establish wheat-fed bioethanol plant in Hull, the UK. On 26 June 2007, together with British Sugar, BP and DuPont have started building a USD400 million bioethanol plant in Hull, with a capacity to produce 420 million litres of bioethanol annually from local-grown wheat. This joint-venture operates as Vivergo Fuels Ltd can produce 1/3 of the UK’s bioethanol demand (AB Sugar, 2016). The latest update, Associated British Foods acquired BP’s stake in May 2015 to become the majority shareholder (Sapp, 2015).

4.1.6 Project 6: BP and D1 Oils, 2007. This project was to produce biodiesel for commercial scale. On 29 June 2007, D1 Oils and BP have established a 50:50 JV partnership, named as D1-BP Fuel Crops Limited, to plant Jatropha curcasan (D1 Oil PLC, 2009). The JV was aimed to produce biodiesel for commercial scale which has the taken-in investment of $160 million by both parties over five years. The activities included planting in India, Southern Africa and South East Asia; expected to cultivate 1 million hectares (BP, 2007a; 2007b). The latest update showed this project has completed.

4.1.7 Project 7: BP, Arizona State University and Science Foundation Arizona, 2007. This project aims at using photosynthetic bacteria for biodiesel production. In November 2007, BP has established a research partnership with Arizona State University (ASU) and Science Foundation Arizona (SFA) to develop biodiesel. The SFAz agreed that a group of ASU researchers received USD2.2 million over two years, while BP collaborated with ASU, contributed funds equal to SFA’s grant. As such, a total of UDS4.4 million has been injected into this project (Flinn Foundation, 2007). The photosynthetic bacteria in the production of biofuels reduce cost and complicated processing. Besides, the microbial cultivation, using solar energy and a controlled production facility, can be set up on idle land. The bacterial biodiesel production allows the technology to be placed adjacent to power generating stations and the utilisation of flue gas as a carbon source (Caspermeyer, 2007). This helps towards total carbon reduction as a whole. With the latest information in 2011, Cyanobacteria is genetically modified to produce fatty acid (Liu et al., 2011).

4.1.8 Project 8: BP and Tropical BioEnergia S.A, 2008. This project is to expand its operations in Brazil ethanol industry, which is sustainable and competitive for the global market. 2008, In 2008, BP is a JV with Tropical BioEnergia, to help BP meets its goal of providing more quantity, secure, green and affordable biofuels (BP 2008a, 2008b). BP has a 50% stake in Tropical with USD59.8million financial injection. On 14 September 2011, BP has agreed to pay a total of approximately US71 million in cash to acquire the remaining 50% of the share in Tropical BioEnergia S.A from Maeda S.A. Agro-industrial and LDC- SEV Bioenergia S.A (BP, 2011b) (BioFuel Digest, 2011). Following the acquisition, BP will own and operate Tropical BioEnergia's mill in Edélia, Goiás state. BP also operates mills in Itumbiara, Goiás and Ituiutaba, Minas Gerais (BP, 2011a). The total planned combined crushing capacity of Tropical BioEnergia when fully developed, is expected to be five million tonnes of sugar cane per year. At full capacity, the mill will have a production capacity of about 450 million litres of ethanol equivalent per year (BP, 2011b).

4.1.9 Project 9: BP and Verenium Corporation, 2009. This project was to develop and commercialise cellulosic bioethanol from non-food feedstocks. On 18 February 2009, BP and Verenium Corporation announced the formation of a 50-50 JV, under the name Vercipia Biofuels, to develop and commercialise cellulosic bioethanol from non-food feedstocks (BP 2009e, 2010), (Verenium Corporation, 2009). -This JV is intended to progress the design and engineering required for the development-one of the US first commercial scale cellulosic bioethanol facilities, located in Florida. In October 2012, BP announced that it has cancelled the planned construction of a commercial-scale cellulosic ethanol plant in Florida, and instead will focus on licensing its 2G technologies. In addition,
in 2015, BP has closed down its US. Cellulosic operation in Jennings, the Highland feedstock farm in Florida, a technology centre in San Diego, and some activities in Brazil, Houston or London (Tobben, 2014; Shumkov, 2014; Kaufman, 2015). The latest update shows, BP lignocellulosic technology in Brazil has been ceased.

4.1.10 **Project 10: BP and Martek Biosciences, 2009.** This project works on the production of microbial oils for biofuels applications. On 11 August 2009, BP and Martek Biosciences Corporation announced the signing of a Joint Development Agreement (JDA) to work on the production of microbial oils for biofuels applications. The partnership combines TRM and operational capabilities to advance the development of a technology for the conversion of sugars into biodiesel (BP, 2009f; Martek Biosciences Corporation, 2009). The JDA crystallised the combination of Martek’s leading know-how in microbial lipid production, with BP’s expertise in biofuels markets, applications and commercialisation. Besides, BP agreed to contribute up to USD10 million to this initial phase of the collaboration which leverages Martek’s expertise. Martek will perform the biotechnology R&D, whilst BP will contribute to biofuels value chain know-how (BP, 2009f).

4.1.11 **Project 11: BP and Companhia Nacional de Acucar e Alcool (CNAAG), 2011.** This project is to increase biofuels production. BP has agreed to pay approximately USD680 million to acquire 83% of the shares of CNAAG. Since this acquisition, BP will become the operator of two existing producing ethanol mills-located in Goiás and Minas Gerais states, which the third CNAAG mill is currently under development in Minas Gerais state (BP, 2011a).

4.1.12 **Project 12: BP and the DSM (Dutch Chemical Company), 2011.** In California, BP and Dutch chemicals company DSM have invested an un-disclosed amount in Carlsbad-based Verdezyne to fund the company’s start-up operations during the next two years as well as to build pilot plants that will produce both ethanol and adipic acid from cellulosic feedstocks (BioFuelDigest, 2011b; Bevill, 2011). This project has completed with no further information traced.

4.1.13 **Project 13: BP Biofuels and Texas AgriLife Research, 2012.** This project was to develop and commercialise cellulosic feedstocks for the production of advanced biofuels. BP Biofuels and Texas AgriLife Research, part of The Texas A&M University System, have signed a three-year agreement to develop and commercialize cellulosic feedstocks for the production of advanced biofuels (Lane, 2012; Tisheva, 2012). The partnership made use of AgriLife Research’s high biomass energy crop breeding programme and the fact that BP Biofuels is one of a small number of global energy companies that grow crops for the production of liquid fuels on a commercial scale (Tisheva, 2012). The project has two integrated components- plant breeding and production agronomics. Plant breeding efforts focused on developing new varieties of pearl-millet napiergrass, king grass, energy cane and miscane suitable for cellulosic biofuel feedstock production along the U.S. Gulf Coast and the other was production agronomics. The integration of plant breeding and production agronomics enabled BP Biofuels and AgriLife Research to develop elite genetics and production guidelines for future growers (Lane, 2012). This project has completed with no further information traced.

4.1.14 **Project 14: BP and Pure Biofuels del Peru, 2014.** This project is to expand the companies’ operations and marketing capabilities. In September 2014, BP announced an equity investment of an undisclosed amount in Pure Biofuels del Peru. Based in Lima, Pure Biofuels are the leader in the Peruvian refined fuels and distribution services markets. Pure Biofuels currently has over a million barrels of liquid fuel storage at the Port of Callao, the largest port on the Pacific Coast of South America. The company markets and distributes liquid fuels and biofuels in both the local and regional markets and also owns and operates a state-of-the-art biodiesel refinery co-located in the storage and dispatch terminal in Callao. The strategic acquisition will benefit both companies expand the companies’ operations and marketing capabilities, thus help accelerate the companies’ growth
prospect (Lane, 2014). The latest update shows, Air BP and PBF have signed 50/50 aviation fuel joint-venture agreement in Peru (BP, 2016).

4.2 Discussion

Through its website (BP, 2017b), BP believes, biofuels if produced correctly, they reduce the impacts of climate change without affecting food supplies and without threatening the biodiversity. The next generation biofuels (NGB) feedstock can have a positive impact since non-food potential energy crops are largely and naturally available which possibly can be the NGB feedstock.

Albeit biofuels business is as one of the renewable energy profiles, which is foreseeable to be lucrative, biofuels business is completely new for BP. Thus, biofuels have placed an enormous challenge on BP’s existing knowledge on energy, operation and management system for the company’s a-century business is rooted in fossil-fuel exploration, production, refining and marketing. In reality, BP does not have adequate institutional knowledge in developing biofuels from the biotechnology sphere; as well as it does not have the capability in producing biofuels. To date, all collaborative NGB development projects are established between BP and its cross-border biofuels partners (biotechnology institutions, R&D organisations, local authorities, agriculture partners and others). Since these biofuels partners have the expertise and biotechnology knowledge; they could help BP to materialise the NGB technology required in a speedy manner.

5. Conclusion

As a way to ensure those high potential NGB developments could be successful, both the biofuels partners and BP’s motivations in profit-and-risk-sharing have to be aligned and complementing. The strategy of joint-venture partnership in NGB development is aimed at knitting the seamless match among the stakeholders, in order to generate the momentum of commitments (BP with the energy market knowledge while the biofuels partner with its biotechnology expertise) to embark on the high potential, complex and large scale NGB projects with consentaneous profit-risks sharing in the NGB investment, research and development.

For highly uncertain and time consuming NGB development projects that require trial-and-error such as biofuels feedstock research by EBI, Photosynthesis bacterium research with Arizona State University, Conversion sugar for biofuels with Martek and feedstock plantation Jatropha in India, contracting out is the main strategy. According to Khalil (2000), a company like BP can conduct R&D without having to invest heavily in an in-house R&D on its human capital and technical infrastructure. This approach is implemented since BP would utilize its funder authority when the project comes to a dead-end.

The BP NGB TRM (Figure 1) represents a technology planning process that identifies the latest NGB technology, selects the technology partners, and develops the NGB technology acquisition strategy to meet the demand of green and sustainable NGB. The different modes of collaboration (joint-venture and contracting) are aimed for the NGB commercialisation. By the end of the project, BP can utilise the research findings as assets for profit making. These collaborations could generate two implications: Firstly, the knowledge transfer from biofuels partners with BP, enables BP gradually building its institutional knowledge associates with biotechnology for the NGB innovation and production in building long term competitive advantage.

Secondly, these biofuels partners would have the opportunity in profit-seeking with BP. The research outcomes could be patented for commercial purposes. Up to date, BP has fourteen the NGB development projects undergoing, which patterned mainly at two modes of collaboration established for technology acquisition: equity joint-venture (JV) and contracting out. All of these modes are aiming to lower the risk exposure, pooling the resources needed from their respective partners and connect with the mutual benefitting economic motivations, as well as wealth creation.

Generally, the information on the BP NGB development project is published widely in order to disseminate the information into the markets (for informing and engaging public) while for policy maker (in strengthening the policy framework and policy measure). Interestingly, after the NGB
projects are mapped as the TRM, it is agreed that this information sharing not only meant to report technologies under development, but also to declare and claim the technological territory for narrowing the gates of new entrants into the similar business, as well as to foreclose the technological opportunities available.

To date, most of the NGB development projects are still in progress. The latest webpage of BP found in June 2017 solely promotes the Brazilian biofuel, which is sourced from 10 million tons of sugarcane per year. It seems this sugarcane bioethanol project is the key project that BP has placed as a milestone in its NGB development. With three sugarcane processing units owned in Brazil, BP seems to have high confidence in sugarcane bioethanol. This is backed by the Brazilian Government (BP, 2017b).

With Brazilian sugarcane on the limelight, this has also sent a message to the developing countries in South East Asia like Malaysian universities and laboratories start to pursue the biotechnology research on potential non-food biofuels feedstocks which are largely and naturally inhabited. Looking at BP partnerships with American universities this puts a vast opportunity for research and commercialisation to be adopted by Malaysian higher education institutions to accelerate their research output on renewable energy, either working with those world oil companies (like BP), or collaborate with our National Petroleum Company-Petronas.

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**Figure 1:** BP’s Next Generation Biofuels Technology Roadmap

- **2006 (START)**
  - BP + Butamax
    - Develop advanced biofuel biomass
  - BP + TERI
    - Produce biodiesel from farming

- **2007**
  - BP + Tropical BioEnergia S.A
    - Commence their operations in Brazil

- **2008**
  - BP + EBI
    - Develop and commercialize application of biocatalysts in the biofuel sector
  - BP + Butamax
    - Launch biobutanol commercial production

- **2009**
  - BP + Tropical BioEnergia S.A
    - Establish production of 2G biofuel and various applications of biocatalysts in the biofuel sector
  - BP + Merck
    - Establish commercial production of high-performance biocatalysts

- **2010**
  - BP + CNAA
    - Establish production of ethanol
  - BP + DSM
    - Establish plant to produce ethanol and synthetic lubricants

- **2011**
  - BP + Tropical BioEnergia S.A
    - Commence their operations in Brazil
  - BP + Pure Biofuel del Perú
    - Expand the company’s operational and marketing capabilities

- **2012**
  - BP + Butamax
    - Establish advanced biofuel production
  - BP + Verenium Corporation
    - Establish commercial scale bioethanol facilities, located in Florida

- **2013**
  - BP + Tropical BioEnergia S.A
    - Fully acquire the share in Tropical BioEnergia S.A
  - BP + Martek Biosciences
    - Establish microbial biodiesel production through fermentation

- **2014**
  - BP + Verenium Corporation
    - Cancel the planned construction of cellulosic bioethanol plant in Florida
  - BP + Desert Power Fuel
    - Establish commercial scale bioethanol facilities, located in Florida

- **2015**
  - BP + Butamax
    - Establish advanced biofuel production
  - BP + DSM
    - Establish plant to produce ethanol and synthetic lubricants

- **2016**
  - BP + Tropical BioEnergia S.A
    - Establish production of ethanol
  - BP + Desert Power Fuel
    - Establish commercial scale bioethanol facilities, located in Florida