Strategic leadership for an energy world in transition

A case study of Royal Dutch Shell

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Abstract

In the last few decennia fossil-based resources have formed the backbone of the world's economy. However they are a limited resource. At the same time, the world population is estimated to increase by two more billion people by 2050, which will lead to an increase in the energy demand. With currently limited advances in the large scale deployment of renewable energy technologies, carbon-based resources will continue to play an important role in the near future. In addition, increased concentrations of CO_2 emissions associated to surging consumption of fossil-based resources are already taking their toll on the environment and can lead to catastrophic weather events if the emissions will continue at current rate. This creates a truly unique environment for oil and gas energy companies, which, while pursuing their traditional role as energy providers, will have to minimize the environmental footprint associated with their operations and ensure a sustainable energy supply. This essay explores the strategic elements that successful companies apply to succeed and thrive in a volatile world, with emphasis on the tools and activities that give Royal Dutch Shell, one of the largest oil and gas companies, a leadership position in the energy industry.

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"Meeting energy demand is a massive challenge. But so too is the need to tackle the real and growing threat that climate changes poses."
Ben van Beurden, CEO Royal Dutch Shell

1. Introduction

In the course of the last century, fossil fuels have shaped the modern world and led to an unprecedented economic growth. It is estimated that 80.6% of the total world energy consumption nowadays is based on fossil fuels [1].
However, this development brought about an increased concentration of greenhouse gases in the atmosphere. In particular, carbon dioxide CO_2 concentrations have grown at an ever increasing rate to values one third larger as compared to the beginning of the Industrial Revolution [2]. At the same time, the global temperature has shown a steady increase, with the 10 warmest years registered after 2000 (in a 134 year record) [3], leading to widespread melting of the ice caps, an increase in the average sea level and more prevalent extreme weather events.

Yet, despite these developments, the energy consumption has continued to increase and will further rise as a result of increasing world population. According to a study recently published in Science, "there is an 80 percent probability that world population, now 7.2 billion, will increase to between 9.6 and 12.3 billion in 2100" [4]. This rapid population growth will further increase the energy demand; exert additional pressure on available resources and the already increased CO_2 concentration in the air. Accompanied by further global warming, this will exacerbate environmental problems. In addition to population increase, energy consumption in developing countries, where living standards increase, is surging, industry is growing and new markets for fossil based fuels and facilities are emerging. And, with few alternative energy resources firmly in place, the world dependence on fossil-based fuels will continue to increase, which will also reflect in rising oil prices.

Clearly, this will affect local policies, where energy security will become a priority. New policies will have to be developed and implemented, to provide long-term, sustainable and renewable energy solutions and deal with increased impact of climate changes. Policies to address such issues as alternative energy resources with most promising potential and the best energy resources combinations to address local needs and lessen dependency on imports. Financial incentives, to accelerate the development of more efficient/renewable energy technologies as well as to quickly deploy these technologies. This will also foster a ripe environment for new businesses to emerge and claim a spot in the energy landscape. Some changes have already been made, but they are at an infancy stage and a lot of work still needs to be done. Renewables account today for little more than 5% of the global power output and cater for nearly 3% of the energy consumption [5]. Yet they come with a financially intensive subsidy regime, which countries such as Germany, one of Europe's leading renewable producers, are already grappling with.

Not only governments, but also private consumers can contribute by opting for changes around their homes, such as using more efficient heating systems, double glazing, loft insulation or the installation of solar panels (on south facing walls) or wind turbines, where wind is not in short supply. This can even warrant a small financial gain, by selling the surplus energy back to the national grid, a popular incentive in Germany, where power companies are paying about five times more as compared to companies in other European countries [6]. In addition, opting for blended fuels or hybrid cars can make a substantial impact on the reduction of road traffic emissions, which account for 17% of the total CO_2 emissions worldwide [7].

Clearly, meeting the increasing world energy needs, see Figure 1, will impose a significant strain on available resources [9]. And a transition from fossil based fuels to a renewable energy based society will have to occur to ensure low CO_2 levels and avert a catastrophic temperature rise. But, as Giussepe Tomasi di Lampedusa put it "If we want things to stay as they are, things will have to change" [10].

In this essay, I will focus on the strategy of Royal Dutch Shell, one of the major oil and gas "supermajors", to meet the energy demand and mitigate the effects of CO_2 emissions.

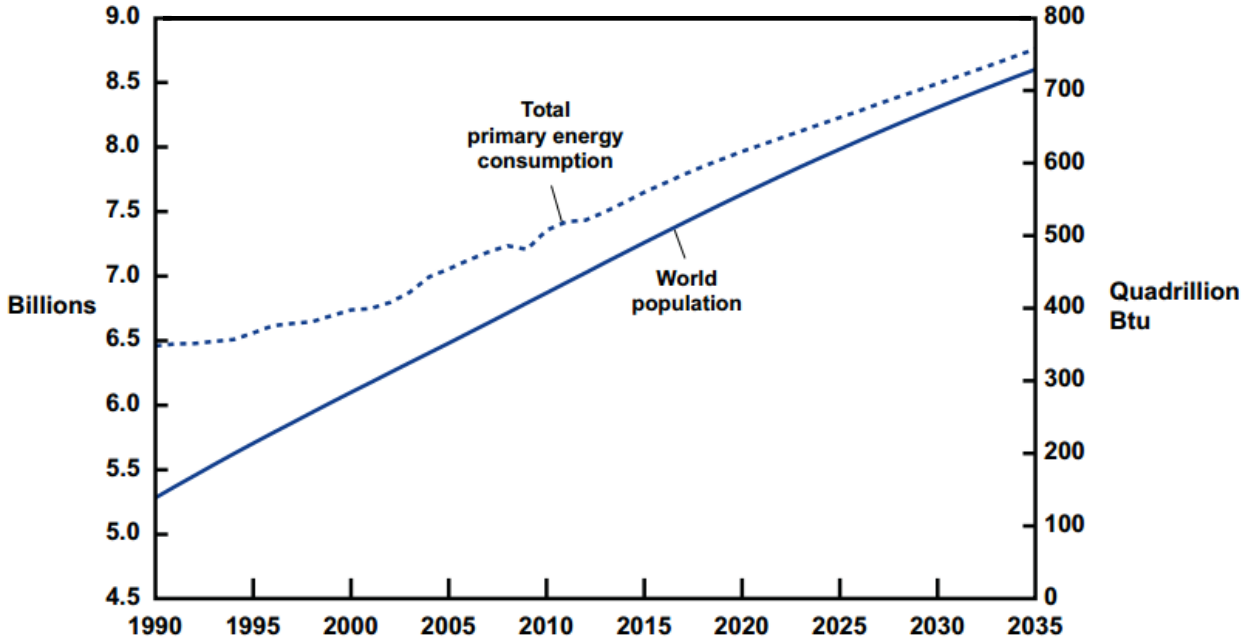

Figure 1. Growth in world population and primary energy consumption 1990-2035 [8].

2. Leadership and strategy for a world in transition

Royal Dutch Shell is an Anglo-Dutch multinational oil and gas corporation, composed of more than 300 companies in more than 90 countries around the world. All of these companies are co-owned by two holding companies, one British (Shell Transport & Trading) and one Dutch (Royal Dutch Petroleum). The name Shell stems from the currency used by the British founders of the company to trade in the Far East, which were seashells. The companies merged in 1907 and ever since, the primary business of the company has been the production of oil and gas. Shell is vertically integrated, with activities ranging from exploration and production to refining, petrochemicals, marketing and trading. But whereas fossil fuels will continue to play an important role in the future energy mix [11], the transition towards a renewable energy system will change the energy landscape significantly.

So how can Royal Dutch Shell thrive and continue to play a major role in the energy sector in the future? Clues can be found in a study conducted between 1988 and 1994 at Stanford University by Jerry Porras and James Collins, who asked 700 chief executives of large and small US companies to name firms that they admired the most. From the pool of answers, they selected the top 18 companies, paired them up with their competitors and started to look at the differences between them. What Porras and Collins found was that "most admired companies combined sensitivity to their environment with a strong sense of identity". But also, that "visionary companies display a powerful drive for progress that enables them to change and adapt without compromising their cherished core ideals"[12]. After an extensive research of many companies, Meyer and De Wit [13] attributed this ability to the capability of these companies to combine two elements: 'building the future', the agility and flexibility to face the urgent, short term challenges, with 'shaping the future', which is a focus on the important long term challenges, even when there seems no urgent need. These are however two contrasting elements. 'Building' is about managing the short term, about tackling urgent issues first, while maintaining the heritage of the past. By contrast, 'shaping' is about innovation and forward thinking, is about tackling important issues with focus on the long term. But the combination of these elements is what gives a company resilience to both short term as well as long term changes and challenges. It is this combination that constitutes great strategic leadership.

According to Meyer and De Wit [13], leading companies have the ability to combine mutually exclusive elements in a cohesive way, the ability to manage paradoxes. So, how can a company such as Shell manage economic profitability and a competitive dividend for shareholders with social responsibility? How can Shell meet the increasing world energy demand and also mitigate the effects of CO_2 emissions by fossil fuels? The answer is simple: through

innovation. The vision of Shell is to become the most competitive and innovative energy company" (Peter Voser, Shell CEO, 2009-2013). Because "technology and operational experience are keys to unlocking a sustainable future for the global energy" (Gerald Schotma, Shell Chief Technology Officer 2009-2014).

3. Leadership and strategic innovation at Shell

Technology development plays a very important role in Shell. It is what will enable the company to develop future energy systems that will ensure economic progress in a sustainable way. And it is the key to reducing the footprint of operations and CO2 emissions. This is also reflected in the budget for research and development R&D, with investments exceeding 1 billion$ every year, on innovative projects to be applied in a time horizon spanning from 2 to 20 years. This is the biggest budget invested in research among all the majors. And it shows. In 2012 Shell featured among the TR50 list by MIT Technology Review, which brings together public and private companies that gain a clear competitive advantage by bringing original and valuable technology to the market on a significant scale [14]. According to Jason Pontin, editor in chief of the magazine, "the TR50 companies are leaders. They are setting their agenda in their markets and prompting other companies to follow them".

3.1 Open Innovation program

To achieve this, Shell does not only develop technology internally in its R&D centers, but has an extensive collaboration network, from universities to technology companies to research institutes and individuals. This, in a quest for excellence in research and from the recognition that no company can develop the required advanced technology alone. But most value can be generated by making the most of complementary strengths brought by different parties. Numerous programs are available within the company to facilitate this open innovation approach.

3.1.1 GameChanger

The GameChanger program within Shell has been developed to support out of the box ideas and is seeking for proposals for radical innovation. The program is open both to the public and to Shell employees. Everyone is eligible and can submit their ideas via the Shell website [15] for review. The selection panel is formed by Shell employees with extensive experience and various fields of expertise. Once the proposal has received favorable appraisal, it undergoes a second selection stage, this time by an extended panel, consisting of three members of the GameChanger team and at least three experts in various fields relevant for the scope of the proposal. If successful, the proposals receive funding for 2 to 3 years, during which the initial idea is developed, according to an agreed plan, to a proof of concept. If this last development stage is reached successfully, GameChanger can help take the invention to a further stage, which can be either adopted by Shell for business use, licensed to an external technology provider or a spin-off company may be started. In its 17 years of existence, the GameChanger has evaluated 1500 proposals and implemented 100. Among these, a massive project to develop a Floating Liquefied Natural Gas (FLNG) plant, as described in section 3.3.2.

3.1.2 Shell Technology Ventures

Shell is also engaging in joint ventures to explore new business and technology. Launched 15 years ago, Shell Technology Ventures [16] works closely with early-stage companies and entrepreneurs and acts as an investor and partner in commercialization. Its investments are targeted towards accelerating the development and deployment of new technologies across the energy sector. While its main focus is on the oil and gas sector (exploration techniques, sub-surface evaluation, well construction and automation), Shell Technology Ventures also invests in renewables (solar and wave technologies) and by-product recycling technologies (CO2 and Sulphur disposal, fluid management). Partners of Shell Technology Ventures are granted the global research capability of Shell, access to Shell's technical experts, to its customer and supplier base and, where necessary, Shell Ventures can also accommodate field trials or serve as a launching customer for the developed technologies.

3.1.3 Shell TechWorks

Opened in 2013 in Cambridge Massachusetts, Shell TechWorks Boston [17] is expected to be the first of several world-wide open innovation centers, bringing together scientists and engineers from various backgrounds, ranging from

automotive, defense, robotics, biotechnology, semiconductors and theoretical science. Their mission: to change the way innovation occurs across Shell, by prototyping technologies already proven elsewhere and having them ready for deployment in 2 years. Technologies currently under development range from human-robot interaction (to develop underwater unmanned vehicles with special detection capabilities), software as well as hardware design and development (to assist drilling operations) to sensor development and integration.

3.1.4 Shell Ideas 360

Shell Ideas 360 [18] is a global student competition meant to support the development of innovative ideas to tackle Energy, Food and Water issues. A number of 100 participants are selected from an international pool of applicants to participate to the next round of the competition, during which their ideas are further developed with the help of a mentor, a Shell technical matter expert. Among these, only 5 individual participants or teams are selected for the final. The winner of the competition is awarded a place in a National Geographic Expedition. In addition, the best ideas, even if not the winning ones, are considered for funding by the GameChanger program.

3.2 The Shell scenarios

The scenarios were pioneered in the 1960s, by a team of economists, engineers and scientists at Shell, led by Pierre Wack. For the first time, they looked at how the course of the company as a whole may be impacted by the complex interplay between politics, economics and energy. In the early 1970s, they shared their hypotheses with Shell management and included in the analysis the possibility of a global oil crisis. Shortly after, in October 1973, the Yom Kippur War broke out and resulted in an Arab oil embargo, in reaction to the support for Israel from the Western countries. This rippled into a massive stock market crush and triggered a global recession. It also brought Shell management to the realization of the importance of the Scenarios as a tool to challenge conventional, business as usual, thinking and to consider alternative future developments in their strategic decision making process. The Scenarios also helped the company to anticipate and respond to another oil shock in 1979 and to the decline, and eventual collapse, of the Soviet Union. In the 1990s, the market liberalization, globalization and the rise of environmental concerns relating to increasing CO2 emissions were also trends featuring in the Scenarios. They also brought sustainable development at the forefront, emphasized the importance of natural gas and explored what impact disruptive technologies (such as electric mobility) may have on the future energy landscape. These helped the company re-inforce its natural gas businesses and recognize the importance of gas in the global future energy mix, together with biofuels [19].

From 2000 on, the Scenarios envision an “era of volatile transitions over the next decades“, with growing environmental stresses due to population rise and global increase in the energy demand. Taking these three key hard truths of the current reality as a building blocks, “The new Lens” Scenarios, developed in 2013, explore what may lie ahead in 50 to 100 years from now. Whereas in the initial years after the Scenarios were started, six or even seven scenarios were put forward by the team, their number decreased to three, and then to two at the beginning of the 1990s. This was done to enhance usability, by providing clear and concise stories, to serve as common vocabulary for debates and encourage creative thinking across the business.

The two “New Lens” Scenarios are called “Mountains” and “Oceans” and provide two perspectives at the opposite spectrum of the forces that will help shape the future [19,20].

“Mountains” depicts a “top-down” world, with a strong role of the government in shaping policies that will help transform the global transport network and create more compact and energy efficient city infrastructures. In the world on “Mountains”, shale and tight gas resources play an important role in the global energy supply. Gas becomes the new backbone of the energy system, see Figure 2, ending the 70 years long supremacy of oil. Also, technologies to accelerate carbon capture and storage are actively pursued, which, together with the gradual replacement of coal by gas, help to develop and support a cleaner energy system.

“Oceans” provide a “bottom-up” perspective of a future world in which the energy system is shaped by market forces. This is a volatile, but more prosperous world as compared to the one of the “Mountains”, in which globalization becomes stronger. Emerging economies continue to grow and surge the energy demand, which in a political climate where supply energy policies lag behind, push the supply and demand boundary even further at the expense of

resource stresses. The development and shale and tight gas assets are disappointing outside the United State and as a consequence the growth in coal and oil production worldwide is observed. The strain on resources leads to increased oil prices, with the result that new, expensive technologies become economical to use and exploit high-cost resources. In addition, higher energy prices stimulate the development of renewable energy resources and by 2060 solar energy becomes the world's largest energy source. The deployment of carbon capture and storage technologies occurs late, despite increasing levels of greenhouse gas emissions.

While not predictions of the future, Scenarios explore how current realities and trends may unfold in the future and attempt to capture their potential implications. They hold an important commercial value by helping Shell strategically plan its activities and growth in a volatile world.

Figure 2: World's number one energy resource according to the Mountains and the Oceans Scenarios. [20]

3.3. Gas technologies

Gas will continue to play an important role in the energy mix and in combination with carbon capture and storage, can have a significant role in reducing CO2 emissions. This is because it burns much cleaner as compared to coal or oil. It is an abundant resource which, based on technically recoverable resources, is estimated to last for the next 250 years [21]. Shell is actively pursuing the development of gas-related technologies and is a pioneer in liquefied natural gas, a process in which cooling the natural gas to -162°C turns it into a liquid and reduces its volume by 600 times. This makes natural gas compact and easy to transport economically and efficiently.

3.3.1 Pearl GTL

Shell has built the world's largest gas-to-liquids plant, Pearl GTL [22] The plant is situated about 80 km North of Doha, Qatar, the third largest natural gas reserves holder in the world after Iran and Russia. The project was initiated in 2006 in a partnership between Shell (25%) and Qatar Petroleum (75%) and led to the construction of a fully integrated facility, from off-shore wells, transport to processing facilities of GTL products. Every day, about 1.6 billion cubic feet of natural gas from the North Field is processed at Pearl, using the Shell Middle Distillate Synthesis technology that took Shell 30 years to develop and demonstrate at plant scale. The construction work was finished in 2011 and the facilities are able to process 140.000 barrels of gas-to-liquid products every day.

3.3.2 Prelude FLNG

In 2011 another large scale project was initiated, the construction of Prelude FLNG. Initially, this project started as a GameChanger idea, a truly "revolutionary technology developed by Shell… has the potential to change the way we produce natural gas." (Neil Gilmour, Shell VP Integrated Gas Development). The project was initiated after the discovery of the "Prelude" reservoir, 200 km off-shore Australia, when it became clear that the construction of an on-shore LNG facility to process the natural gas was not profitable. Four years after the field discovery, the Prelude FLNG [23] project was started, to build the first floating LNG facility in the world. It will be fully anchored on the sea floor and the natural gas from the wells on the sea floor will be captured and processed by the LNG facilities on board, see

Figure 3. When completed, the technology will have the potential to fully change the way off-shore gas fields are currently being developed and produced. And it will allow tapping into reservoirs currently considered too expensive to produce using available technologies. Hundreds of engineers from all over the world are currently working to adapt technology for off-shore conditions. The scale of the facilities is truly impressive: the decks will be longer than 4 football fields end to end, the storage capacity will be equivalent to that of 175 Olympic swimming pools and, with its cargo tanks full, it will weigh about six times as much as the largest aircraft carriers. Once finished, the facility will be about one quarter the size of a similar gas-to-liquid plant onshore and it will be kept safely moored in position, even for the worst weather conditions, by thrusters delivering 6700 horsepower.

Although initially an exclusive Shell initiative, the project is now shared with Korea Gas Corporation (10%), the Taiwanese CPC Corporation (5%) and INPEX (17.5%), a Japanese company [24, 25]. Once finished, the facility is expected to produce at least 5.3 million tonnes of liquids every year, enough to cover the gas needs of Hong Kong.

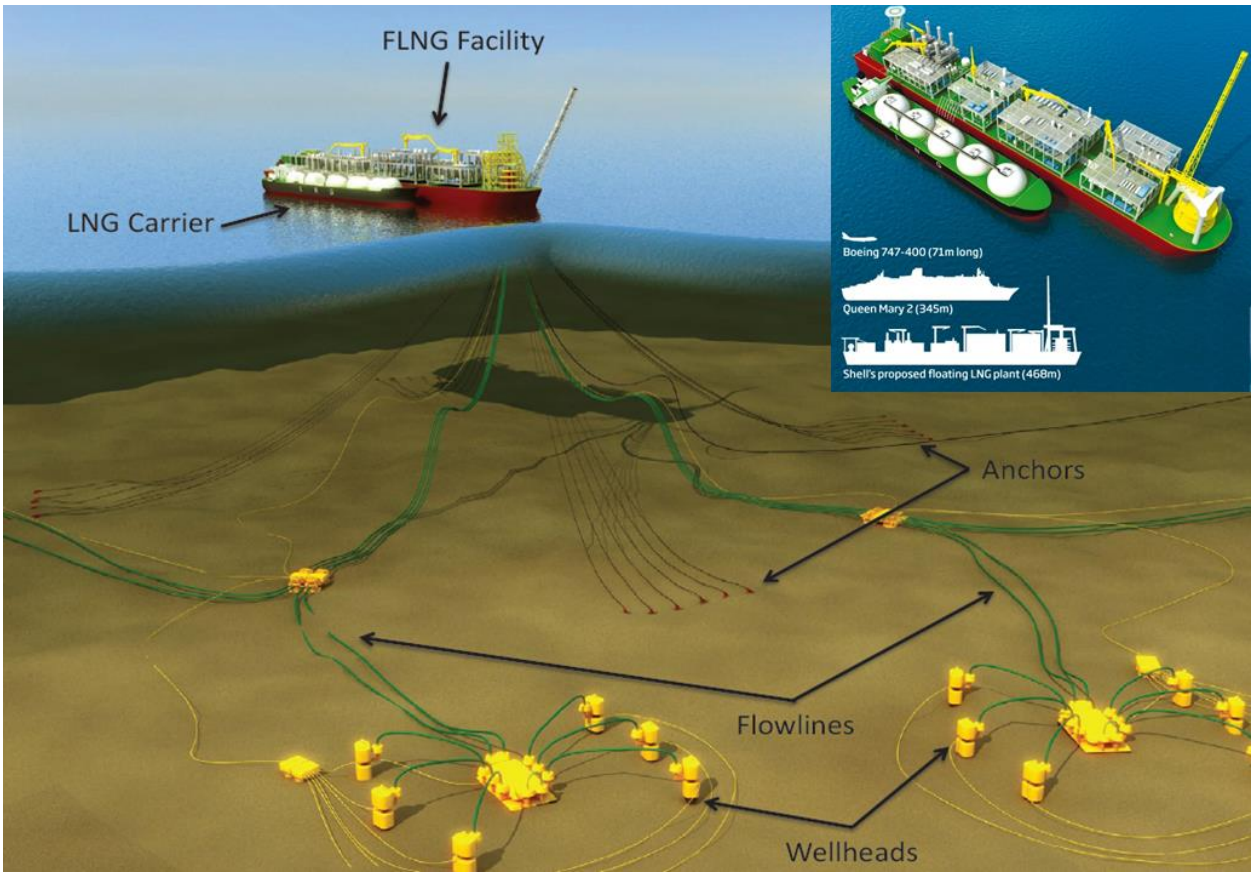

Figure 3. Artistic impression of Prelude FLNG [cite]

On the 8th of April 2015, Shell announced the acquisition of the British BG Group, at around 63 billion US$ price [26]. This strongly enhanced the business portfolio of the company and enforced its position on the gas market. And fits within the framework of the "Mountains" view of the scenarios, in which gas will play a dominant role in the future energy landscape.

3.4 Renewable energy sources: Wind energy

Stemming from the recognition that a transition to a sustainable energy supply is necessary, Shell has also been exploring alternative energy resources. One of these is wind energy. The company has a rather long history concerning the development of wind parks, both on- and off-shore, with wind projects active in the United States and

in Europe. Using its experience in building oil and gas platforms in harsh environments, Shell, together with Nuon and the Dutch government have built the NoordZeeWind park, see Figure 4, one of the largest windmill parks in the North Sea. The park is regarded as a large scale demonstration project. It hosts 36 windmills spread over an area of 27 km^2. Each individual mill is 55 m high, with steel monopile bases, weights 115 ton and has a capacity of 3 MW. Special corrosion protection has been used to ensure a long lifetime for the windmills. The total capacity of the park is 500 MW, enough to sustain 100.000 households. When compared to a coal-based energy plant, the windmill park saves 1 million tonnes of CO_2 emissions.

Not only the environment, but also marine ecosystems benefit from the windmills. After the park was contructed, a study was carried out to investigate the effect of the windmills on the coastal seal communities. The turbine noise was considered a potential factor to disturb and drive away the seal population in the park area. Interestingly, the effect was exactly the opposite. As a result of the lack of fishing and creation of hard habitats (on the monopile bases) the fish population increased and this attracted seals to the park [27].

Although Shell has been actively pursuing alternative, wind energy projects, the company has not yet taken large steps towards difersifying its business portfolio. Most projects are still in research phase, with potential to large scale investments, once the technology becomes more profitable.

Figure 4. Shell NoordZeeWind park in Egmond aan Zee. [28]

3.5 Harnessing solar energy for enhanced oil recovery

Whereas not strictly speaking a renewable energy project, the collaborative project between GlassPoint [29], Shell and Petroleum Development Oman, is an example of innovation and ingenuity. It shows how, by using the local available resources in combination with new technologies, one can make the most of available resources.

Using a technique called enhanced oil recovery, difficult to access, heavy oil, is generally extracted from reservoirs using steam. Large amounts of valuable natural gas are currently used to generate the necessary volume of steam required for this operation. However, recognizing the potential of the Glasspoint's solar steam generators, Shell Technology Ventures, in collaboration to the Omani government, have invested in the technology and recently

deployed it in Oman. As a result of its successful implementation, the consumption of natural gas for the enhanced recovery operation has been reduced by 80% [30, 31, 32]. In short, the GlassPoint technology uses large, curved aluminum mirros to harness and concentrate the sunlight onto a boiler tube filled with water. As a results of the energy transfer, the water boils and high pressure steam is produced. The system generates an average of 50 tons of emissions-free steam daily. This is injected into the Amal West oilfield reservoir with the effect that it decreases the viscosity of oil and enhances recovery during operation. To protect the sollar collectors from the prevalent wind, dust and sand, the mirrors are enclosed inside glasshouses, see Figure 5. To maintain the glasshouses clean and maximize the efficiency of the mirrors, an automated system has been set in place. This also minimizes maintainance costs.

Figure 5. Glasspoint solar steam generators at the Amal West oilfield [29].

This enabling technology has a great impact in Oman where, according to the National Center of Statistics and Information, the total natural gas consumption rose to 39.114 million m^3 in 2013. A share of 9.047 million m3 of this amount (almost 23% of the total country's use) was used exclusively by the oil industry. According to Omani officials the technology will have profound implications on the Omani economy, by diverting the natural gas from oil production to other industries: "Our portfolio is designed to secure the future prosperity of Oman and its people by creating a diversified asset base to complement the country's wealth of natural resources. GlassPoint's technology can provide a multitude of tangible economic benefits to Oman and any country with abundant sunshine and a scarcity of alternative fuel for thermal EOR" (Abdulsalam Al Murshidi, Executive president of of Oman's State General Reserve Fund) [30].

3.6 Carbon capture and storage

Carbon capture and storage (CCS) is one of the most promising technologies to reduce increasing CO2 levels from the use of fossil fuels. It is estimated [Special Report on Emissions Scenario, assuming an energy demand increase of 1.9% per year,] that by 2030 11 billion CO2 emissions will come from natural gas, 8.4 billion form coal and 17.2 billion from oil. Therefore, within the framework of its sustainability policy, the CCS technology is very important for Shell. This is also reflected in the breadth of activities within the company ranging from research to the development of large scale commercial projects, from financing, to public policy debates supporting more governmental

involvement in the creation of supporting CCS frameworks and policies to put a price on CO2. However, before the technology can be deployed, it needs to undergo a large scale demonstration from capture to transport to storage.

In support of its CCS activities Shell actively supports (co-owns together with Gassnova SF, Sasol and Statoil) the Technology Center Mongstad in Norway, the world's largest center to test capture and storage technologies. Also, in partnership with Qatar Petroleum, Shell has signed a 70 million US$ research collaboration contract with Imperial College London, dedicated to the investigation of new CO2 technologies.

Several Shell CCS storage projects are also ongoing worldwide, such as the Otway project in southern Australia, where 100.000 tons of compressed CO2 is injected into a depleted natural gas reservoir, situated at a two kilometers depth. This work is aimed to demonstrate the safety in storing CO2 underground. Shell is also involved in the Gorgon project, the largest CCS project worldwide, together with Chevron and ExxonMobil. Natural gas from the Gorgon field will be supplied to a natural gas plant on Barrow Island, where the produced CO2 will be captured and injected, at a rate of 3-4 million tons per year in a sandstone formation situated at a depth of 2.5 kilometers underground.

Another large scale project is the Quest project in Canada, in collaboration with Marathon oil and Chevron. The project was initiated in 2012 and is supported by the Canadian government which provides a funding of 865 million US$. The CO2 produced during the processing of bitumen to synthetic crude oil at the Scotford Upgrader facility will be captured using a Shell patented technology based on amine solvents. The produced gas, which amounts to about 1.2 million tons per year, will be dehydrated, compressed and transported through via an 84 kilometer long, 12-inch diameter pipeline, to an underground reservoir, 2.3 km deep, for safe storage and permanent containment. This project is the first commercial scale CCS project for the oil sands industry.

Shell is currently assessing other opportunities related to CCS in The Netherlands and Canada [33].

3.7 Biofuels

According the IEA, biofuels could represent about 30% of the world's road transport fuel mix by 2050 [34]. In addition, more than 65 countries are developing policies to encourage biofuels implementation, for energy security reasons, to support domestic agriculture, protect the environment and reduce CO2 emissions. Currently 17% of the total CO2 emissions worldwide are associated to road transport [34].

Shell has been actively involved in biofuels research and development for about 30 years and it is now, according to Pike Research [35,36] one of the best positioned majors in the biofuels market. One of the boldest moves of the company into the biofuels arena occurred in 2010, when Shell founded Raizen, a joint venture with Cosan, a Brazilian producer of ethanol from sugar cane [37]. Shell has been active in Brazil for almost 100 years, mainly in downstream, and it has a large fuel distribution network in the country. The company produces now more than 2000 million liters of first generation ethanol annually [38], using sugar cane feedstock covering about 1% of the total arable land in the country [39].

Shell has also been investing into advanced technologies across the board and is actively involved in developing advanced (second generation) biofuels in collaboration with numerous universities (MIT, Cambridge, Manchester, Exeter) and leading biotechnology companies. One example is the Canadian company Iogen [40] (50:50 equity partnership), with which Shell has been developing a cellulosic biomass to ethanol conversion process, using enzymes. The process combines chemical, thermal and biochemical techniques and it was first successfully demonstrated at commercial scale in 2004, at a cellulosic ethanol plant in Ottawa, Canada. The enzyme-based process developed by Iogen for straw has also been tailored for sugar cane and will be used to turn the fibrous stalks of the plant into second generation bio-ethanol at the newly built Shell mill in Costa Pinto, Brazil [41]. The facility is expected to produce 38million liters of cellulosic ethanol a year.

Shell also has 14.7% stakes in Codexis [42], a California-based company that is developing new enzymes to facilitate the conversion of biomass directly into compounds similar to gasoline and diesel. This technology is specifically targeted to engineer natural enzymes into new variants, capable to perform according to desired specifications.

Another company Shell has been collaborating with since 2007 is Virent [43]. The joint program is aimed at using the Virent patented catalytic chemistry technology to convert plant sugars directly into a range of high performing

transport fluids (gasoline, diesel, jet fuel), identical to those made from petroleum. These fuels have the advantage of a higher energy density as compared to ethanol and can be used in high blend rates in standard gasoline engines (unlike ethanol, for which modified engine designs are required). To accelerate the development of this technology, Shell has recently built a pilot plant at its Westhollow Technology Center in Houston [44].

3.8 Hydrogen for transport

To further contribute to a CO_2 emissions free transportation system, Shell has also been actively involved in creating a support framework for hydrogen and fuel cells technology. These activities are currently run by Shell Hydrogen, a business unit within the Shell Group, which was set up in 1999 and has headquarters in The Hague, Houston and Tokyo. Part of this framework is a research program, in collaboration with several universities, as well as a partnership with in two investment funds, to supply venture capital to early and later stage companies active in the hydrogen sector [45]. Shell Hydrogen is also collaborating with several automobile manufacturers who are currently developing fuel cells powered cars, among which General Motors (HydroGen), Hyundai (Tucson Fuel Cell), Toyota (HCFV-adv), Mercedes-Benz (F-Cell) and since 2004, it has opened several demonstration hydrogen filling stations worldwide. The latest demonstration station was opened in March 2015 in Hamburg [46,47], see figure 6 [48], and is meant to help Shell better understand on-site hydrogen production requirements and its economic benefits. The facility uses water and surplus electricity from the grid to generate hydrogen, through electrolysis. The process generates oxygen, which is vented and hydrogen that is stored in 14-m high tanks and used to re-fuel vehicles. This project was completed within the framework of the Clean Energy Partnership (H2Mobility program). Shell is also involved in other private/public partnerships to support hydrogen-based mobility, among which the California Fuel Cell Partnership, Japan Hydrogen and Fuel Cell Demonstration project, as well as the European Union Fuel Cells and Hydrogen Joint Technology Initiative.

Figure 6. The newly built hydrogen refueling station in Hamburg, Germany. This is the first station in a series of 400 stations planned to be finished by 2023 in Germany, as part of the H2Mobility initiative [48].

4. Conclusions

Although traditionally an oil and gas company, Royal Dutch Shell is also actively involved in a breadth of activities exploring the potential of alternative energy resources. For more than 40 years, the Shell Scenarios have been a powerful tool that helped the company make strategic decisions and maintain its leadership position in a changing energy landscape. The scenarios prepare the company for disruptions, for the unexpected, which, combined with the sustained support for innovation gives Shell a strong competitive advantage. Referring to the framework of Meyer and De Wit, clearly Shell continues to "build the future". The company still pursues its core business activities in the exploration and production of oil and gas, however, a stronger focus has been put in the last years on enhancing the gas business portfolio. This is reflected in the activities of the company on developing large scale gas processing facilities, such as Pearl GTL and mobile gas to liquid facilities such as Prelude FLNG. Also, the recent acquisition of BG, gives Shell a strong position in the natural gas market and consolidates its business portfolio. These developments are also in line with the commitment of the company towards sustainability and reducing the CO_2 emissions footprint of its operations and products. Natural gas produces about 30% less CO_2 emissions as compared to oil through combustion, which combined with carbon capture and storage (CCS) technologies has the potential to significantly reduce the level of CO_2 emitted in the atmosphere. The company is actively pursuing the research and development of carbon capture and storage technologies and is currently involved in several large scale integrated CCS projects worldwide, among which the Quest project in Canada which will become operational at the end of 2015.

In addition to its upstream (exploration and production) industry, another core pillar of Shells' activities is downstream. And, as petroleum-based fuels used in transportation are an important contributor to the total global CO_2 emissions, the company has been actively involved in the development of biofuels, both first generation, through Reizen and second generation, by working in collaboration with Codexis, Iogen and Virent. Since 1999 Shell has also been in pursuit of zero CO_2 emissions technologies and has opened several hydrogen re-fuelling hydrogen stations worldwide.

In addition to alternative (biofuel, hydrogen) energy resources, Shell is also "shaping the future" by actively exploring the impact of renewable (wind) energy resources. While not currently pursued at large scale, these activities provide the company the opportunity to learn, as well as to assess the risks associated to growing the business into new avenues. Ultimately, this knowledge will help Shell smoothly expand its business into renewable alternative resources.

Unlike its competitors in the oil and gas industry, Shell has strongly invested in the development of technologies across the board, not only to increase the performance of its operations and products, but also to explore and understand how new technologies can be integrated into new business opportunities. On the long term, in addition to its main business pillars, upstream and downstream, Shell aims to gain an even stronger position in the energy arena through a third business pillar: renewables.

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