



## The Best Scenario of Carbon Capturing Storage and Utilization (CCSU) in Malaysia

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### ABSTRACT

**Background:** The rapid climate change has grabbed the attention of policy makers, academia, media and industry around the world at the dawn of twenty first century. The combustion of fossil fuels for the satisfaction of energy and transportation needs has enhanced greenhouse (GHG) emissions which harm environment. The Kyoto Protocol of United Nations Framework Convention on Climate Change (UNFCCC) obligated industrial countries to reduce greenhouse gas emissions. However, the member countries like the USA and Japan, which took this initiative failed to achieve their emissions targets. Thus, there is a need to highlight the associated revenue charm for reducing GHG emissions. **Objective:** This paper has therefore focused the identification and calculation of rates for various associated sources of revenue which might help reduce GHG emission in a developing country like Malaysia which having no mandatory emission obligation. **The results:** This paper has identified different sources of revenue and its feasible rates, if Malaysia starts carbon capturing storing and utilization process. **Conclusion:** The paper contributes to limited literature as well as policy, particularly in Malaysian context.

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## INTRODUCTION

The Greenhouse gases emitted through human activities had been causing rapid climate change since 1950. Combusting fossil fuels like coal, natural gas, and oil for satisfying their energy and transportation needs enhance greenhouse emissions. Moreover, industrial processes taking place on land also cause greenhouse emissions. The emissions in atmosphere warm climate that cause many changes in air, land, oceans, and mountains. These changes have both good and bad impacts on human, society, environment, plants and animals. However, the negative impacts of greenhouse gases apparently look more than the positive aspects. Hence, the environmental scientists, policy makers, regulators, Governments and industries all have serious concerns regarding the increasing trend of Greenhouse gases emissions [1] [2]. The Kyoto Protocol of United Nations Framework Convention on Climate Change (UNFCCC) in 1997 is an international treaty initiated for reducing greenhouse gas emissions. The protocol obligated industrialized countries of the world to reduce GHG emissions for controlling anthropogenic interference in the climate. The Protocol supports Carbon Capturing Storage and Utilization (CCSU) as a process that protects the environment from mass GHG emissions. CCSU is the process of capturing, storing and transporting waste carbon dioxide for further processing and productive utilization. The process suggests capturing of waste carbon from large point sources and transporting it to storage sites where it cannot re enter in atmosphere [3].

The success of a CCSU initiative depends many factors including the revenue aspects of CCSU. The captured carbon has many productive uses which in turn not only help offset the costs of CCSU but also earn profit. The CCSU has great potential for generating revenue by supporting the production process of economic goods and carbon trading with industrial countries. However, the limited work on CCSU whether theoretical or practical has been mostly carried out in developed countries. Moreover, the previous literature of science has

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mostly focused the negative impacts of CCSU that harm environment. The positive aspects of CCSU such as expected revenue have not been thoroughly investigated. Hence, there is a need to investigate the revenue aspects of CCSU in the literature of economics and finance. The investigation will help protect environment (as desired) without compromising economic growth. Moreover, the associated revenue will motivate firms and countries for carrying out CCSU. The exploration of revenue aspects of CCSU will not only improve the financial health of the firms but also help boost the economy of the country.

Malaysia as a developing country also has direct and indirect involvement in GHG emissions. The government of Malaysia is planning to start CCSU projects as economic ventures to contribute its share in the global CCSU operations. Subsequently, this paper identifies the expected sources of revenue expressed in monetary terms from CCSU operations based on review of past literature. The paper will help Malaysian Govt. and firms to starting CCSU operations. The paper is also a unique contribution in the literature of finance.

#### *Research problem:*

The UNFCCC has set the goal of stabilizing the GHG concentration. To achieve the goal, the future CO<sub>2</sub> emission needs to be controlled along with undertaking CCSU initiatives as it reduces overall cost of mitigating global climate change. The International Energy Agency (IEA) forecasted 50% reduction in CO<sub>2</sub> emissions across the globe which will control 2 degrees increase in temperature by 2050. The CCSU is expected to reduce 70% costs of the climate change and one fifth of the total GHG emissions by 2050. Similarly, European Union (EU) also projected that cost of climate change controlling will be 40% higher without CCSU by 2030. It has also been estimated that CCSU can reduce annual CO<sub>2</sub> emissions from 9 to 16 billion tones across the globe by 2050 [4].

As of August 2013, there are 12 large scale integrated CCSU projects already operating and expected to rise up to 38 by 2016. The existing projects are capable of preventing 25 million tonnes of CO<sub>2</sub> from reaching the atmosphere each year [5]. As one of the signatories of Kyoto Protocol and member of non-annex I, Malaysia is supposed to participate in the global climate change mitigation exercise. Due to ample space for CCSU undertakings, Malaysia plans to convert it into business opportunities to attract investors. However, the developing countries its firms and investors are yet reluctant in adopting CCSU as economic opportunities. Hence, this paper has focused the revenue aspects of CCSU, which not only identifies the expected sources of revenue, but also calculates its projected rate that could be applied to each individual source in Malaysia.

#### *Research Methodology:*

The methodology of the paper is secondary in nature. This is a pure library and desktop research. First, the data regarding different possible sources of revenue from CCSU undertakings has been extracted from the past literature. Relevant reports and websites of the concerned authorities have been explored and studied. Second, the suitable rates calculated for Malaysia on the basis of other countries experiences and expert opinions around the world. The calculation of these rates has observed the time and conversion of currency factors.

#### *Research Objectives:*

The paper aims to identify the various expected sources of revenue from CCSU. Moreover, the paper also aims to determine rates for these various expected sources of revenue from CCSU in Malaysia.

#### *Study Outcomes:*

To provide a comprehensive analysis of the expected source of revenue from carrying CCSU operations in Malaysia.

To compute feasible rates for various identified sources of revenue from CCSU in Malaysia

To provide recommendations for policy and regulation that control CCSU operations in Malaysia.

To attract investors for investing in this less explored and newly emerged market by providing an insight into the expected sources of revenue from CCSU and their projected rates.

#### *Background of the Study:*

The world had been heavily depending on fossil fuels for its energy needs over the centuries. However, it was first claimed by a Swedish scientist Svante Arrhenius in 1896 that the combustion of fossil fuels emits greenhouse gases that harm environment. GHG emissions had been increasing with a negligible rate since 1880, however, couldn't address properly that time. Hence, it increased dramatically with an alarming rate after industrial revolution [6]. In 1972, most countries of the world attended a conference on environment organized by UN at Stockholm. The conference focused different issues related to climate and environment. Though the conference brought the issue of environment to limelight successfully, but it couldn't ensure the consistency and continuity of the endeavor. Subsequently, nothing worthy happened in the following twenty years. However, after a gap of nearly two decades, the UN again conducted a conference on environment at Rio de Janeiro in 1992. The conference also known as Rio Convention or "Earth Summit" helped developing consensus on the

Framework Convention on Climate Change (FCCC). Subsequently after the two meetings at Berlin and Geneva in this regard, the Kyoto Protocol developed in third meeting at Kyoto, Japan on 11th December, 1997. The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) is an international environmental treaty that enacted on 16th February 2005. It aims to control the rapid climate change by curbing dangerous anthropogenic interference in the climate. The protocol focuses the high level of GHG emissions as a result of 150 years of mass industrialization of the world. It has 192 member countries in two categories, i.e. Annex I and Non – Annex I. The first category Annex I includes the industrialized countries of the world. The countries fall in this category have the legal obligation of reducing GHG emissions. The second category known Non – Annex I includes all developing countries of the world including Malaysia. These countries have no mandatory targets to achieve regarding GHG emission under the protocol. However, the protocol encourages these countries to reduce GHG emissions voluntarily [3].

It had been reported that CO<sub>2</sub> alone accounted for 82% of the total global GHG emissions from 1991 to 2000 [7]. Hence, CO<sub>2</sub> being a bulky contributor in emissions grabbed the attention of scientists towards CCSU. The CCSU not only capture and stores CO<sub>2</sub> in natural storages but also ensure its cost effective and profitable utilization.

However, the countries even actively advocated in favour of the Kyoto protocol like Japan, Canada and members of the European Union couldn't meet their targeted reduction in emissions. Hence, the world has to look at CCSU practices as a money making approach for controlling climate change. Thus, there is a need of an extensive research work on the revenue aspects of CCSU. This paper, therefore, investigates the economic benefits (expressed in monetary terms) associated to CCSU for attracting investors and motivating firms to curb emissions particularly in developing country like Malaysia where there is no mandatory emission. The exploration and estimations of associated projected revenues will not only reduce the pace but also controlling cost of rapid climate change in a developing country.

#### *Significance of the study:*

Most of the previous literature regarding CCSU is relevant to geological, chemical, petroleum and environmental sciences. These studies mostly focused the aspects of CO<sub>2</sub> emissions like quantity emitted, climate change, controlling methods of emissions along with the efficiency and feasibility of re- use and utilization of stored CO<sub>2</sub>. Pilot projects and lab. researchers have been carried out and reported across the globe. However, the missing and less explored aspect of the subject is the economic analysis of different uses of stored carbon. Hence, there is a need of investigating the revenue aspects of CCSU to fill the literature gap. This paper fills this gap in literature of economics and finance.

The investigation of revenue aspects of CCSU will also help improve the adoption of CCSU particularly in the countries where curbing emission is not mandatory like Malaysia. It will help ensure clean, safe and secure environment without compromising economic growth of the country. The study will help control climate change in the countries like Malaysia where industry is rapidly growing. The study also determines the rates for different possible aspects of revenue from CCSU in Malaysia on the basis of the experiences of other countries of the world. The investigation assigns dollar value to various expected sources of revenue from CCSU, which will help firms and country to carry out CCSU projects. This paper creates charm for adopting CCSU both at voluntary and mandatory levels.

#### *Literature Review:*

The world has unanimously agreed that the topic of environment cannot be refused to acknowledge. CCSU is a universal phenomenon that governments, environmentalists, policy makers, and regulators around the world are interested in the capturing and storage of carbon. The core aim of carbon capturing was to control GHG emissions for safeguarding environment and reducing climate change [8]. However, due to high cost and low interest of the stakeholders in CCSU necessitated the investigation regarding revenue associated with CCSU. Though captured carbon has been used for EOR since 1970 but still there is a need of investigating further economic utilizations of captured carbon. The expected revenue will not only help reduce the cost but will also protect the environment with compromising economic growth. The literature unveiled the following possible uses of stored carbon that motivate firms and countries to carry out CCSU.

#### *1. Revenue from Carbon Trading:*

Carbon trading is also known as carbon emission trading. It specifically tackles carbon emissions across the globe. The term carbon trading got popularity, particularly after Kyoto protocol. The protocol aims to control global warming and climate change in future.

Kyoto Protocol of United Nations enacted in 2005, pledged 36 industrialized countries to reduce their emissions up to 5.2% by 2012. Carbon trading is a tool of the Kyoto Protocol for controlling and reducing CO<sub>2</sub> emissions. The Cap-and-Trade is the popular term used in carbon trading. It creates a charm of earning income for companies against reducing their Co<sub>2</sub> emissions. According to cap-and-trade scheme of the Kyoto protocol,

a limit (cap) of emissions has been fixed in the industrialized country by UNO. The total cap has been divided into carbon permits which auctioned among member countries. These countries then distributed these permits into different industries and firms. The permits are a financial incentive that motivates firms to develop environment friendly infrastructure for reducing their CO<sub>2</sub> emissions. For example the two companies A and B of the same country get equal permits. The company A could reduce emissions and saved its permits, while company B couldn't and needs more permits to offset its emissions. Company A can sell (trade) its permits (as saved on reducing emission) to company B for countering its excess level of emissions. However, at the same time company B might help company C (located in developing or country having no mandatory obligation for CO<sub>2</sub> emissions) in reducing its emissions. The quantity of CO<sub>2</sub> reduced by company C is thus replenished in shape of permits or allowance for emission reduction to company B [9].

It is argued that determining fair price and creating a market for carbon emissions will help innovation in low carbon technologies in future [10]. According to the Agricultural Carbon Market Working Group (2010) the Cap and trade is the most cost effective instrument in reducing CO<sub>2</sub> emissions. Carbon trading is more transparent and charming than any other option for reducing emissions. However, effective implementation of the trade requires political will. The carbon trading is considered as an effective tool for reducing carbon emissions and hence a great source of income for the Governments as well as individual firms [11]. It has been advised that Australia should implement and follow the carbon trading for reducing carbon emissions up to 60% to bring it back to the level of 2000 by 2050 [12].

The trade is expanding rapidly specifically after the recommendation of Kyoto protocol. Carbon Finance Unit of world bank reported that 374 million metric tonnes of carbon dioxide had traded in 2005 which was 240% higher than that of 2004 (110 mtCO<sub>2</sub>e). The trade in 2004 was also 41% higher as compared to 2003 (78 mtCO<sub>2</sub>e) (Carbon Market, 2006; Carbon Market Study, 2005). It had been reported that 80% of carbon trade is contributed by Europe. The finance market for carbon in London grown up to 60 billion US Dollar in 2007 and is expected to grow swiftly and expand to US Dollar 1 trillion by 2017 [12].

## 2. Carbon Tax:

Carbon tax is a tax levied on carbon content of fuels. The tax levied on emissions of carbon content of fossil fuels at any stage of product cycle is called carbon tax. The tax is an indirect tax on transaction as compared to a direct tax where income is taxed. It is also known as pollution tax or pigovian tax. There are two forms of carbon tax, namely emissions taxes and energy taxes. The first requires payment of fee, charge or tax on every tonne of GHG emissions released into the atmosphere while the later is levied directly on different commodities of energy [13]. It is argued that CO<sub>2</sub> emissions can be dropped to a proposed level by adopting both carbon and energy taxes [15]. They further documented that the taxes will help a resource shift from coal to gas. An international carbon tax per unit of carbon was recommended by [14] for switching from carbon intensive fuels. stated that carbon tax can promote development of alternative fuels as well as saving of energy [15]. The carbon tax is more effective and significant than energy tax regardless of its rate.

If Norway apply carbon tax of \$65 per tonne on emitted CO<sub>2</sub> can level the emission to that of 1989 by 2020 [16]. The implementation of Carbon and Energy Tax at a rate of 10-15 Euros per ton on emitted CO<sub>2</sub> will reduce the emissions up to 25.8% and will promote the use of renewable energy by discouraging the consumption of coal [17].

## 3. Enhanced Oil Recovery- EOR:

Enhanced Oil Recovery (EOR) is a technique employed for enhancing the production of crude oil. The technique is also known as improved oil recovery or tertiary recovery. It helps extracting 30 to 60 percent or more of the original oil of a well [18]. The current oil production mostly comes from the already matured oil fields. The rate of discovering new oil wells has been slow and steady since last decade. Thus, the increase in oil recovery from these matured wells is a growing concern for oil companies and other authorities to meet the current as well as future energy needs. The enhanced oil recovery (EOR) technique helps to increase the recovery of oil from matured oil fields [19].

The EOR technologies had become a first priority as the oil recovery methods in all the oil producing countries are unsatisfactory. For example, the Latin America and Southeast Asia extract only 24 to 27% while Iran 16 to 17% oil from their oil wells. Similarly, the USA, Canada and Saudi Arabia get 33 to 37 % and Russia up to 40% of its total oil reservoirs. These statistics show that the rest of the percentages i.e. 55-75% represents the residual quantity of oil in these fields. EOR methods are expected to enhance global oil reserves 14 times, by increasing the rate of recovery from 35% to 50% by 2020 [20].

Broadly, the EOR technique can be classified in Thermal, Gas, Chemical, and Hydrodynamic. The use of stored carbon for enhancing oil recovery comes under the broader heading of Gas EOR. Thermal technique especially steam injection is the most preferred EOR technique for larger oil fields. The Hydrocarbon gas injection is preferred in offshore, gas condensed, or the fields far from gas market. CO<sub>2</sub> injection has attracted the attention in recent years, however the CO<sub>2</sub> based EOR is yet limited to the USA particularly Permian Basin.

The CO<sub>2</sub> based EOR is not expected to grow more in near future till the economical production of CO<sub>2</sub> and development of relevant regulatory structure. Chemical EOR methods have made a relatively small contribution to the world's oil production during the last decades. China is the country with the largest oil production coming from Chemical EOR projects [19].

#### 4. Algae Production:

The production of microalgae in open ponds is a source of direct capturing and utilization of emitted CO<sub>2</sub> from power plants. The Algae production requires CO<sub>2</sub> for photosynthetic organism. The little supply of CO<sub>2</sub> thus limits the production of Algae [21].

The continuous decrease of fishery resources is a worldwide concern today. Increase in catching, change in inhabitable environment due to pollution and change in environment across the globe are causing decrease in seaweed communities which assist marine ecosystem in ocean necessary for the nourishment of fishery resources. Hence the enhancement of Algae technology is considered the most important technology for improving inhabitable environment of seaweed communities [22].

Algae industry is a successful emerging industry which strengthens the process of Carbon capture and sequestration (CCS). Algae produced from stored carbon helps producing algae - fuel, biodiesel, ethanol, hydrogen, methanol, bio power, chemicals, feeds, bio plastics and materials used in pharmaceuticals. Algal Scientific Corp. produces algae-based chemicals for foods and beverages. The corporation has declared a successful completion of \$3 million venture for commercializing these products [23]. Algae products simply add to the revenue of the firm which cannot be attained otherwise - underground costly storage of CO<sub>2</sub>. Algae play an important role in mitigation of CO<sub>2</sub> emissions by recycling it into renewable and marketable products rather than disposing it off underground. In addition, the reuse of carbon is also more economical as compared to the costly CCS.

The production process of algae mainly requires a lot of carbon dioxide (CO<sub>2</sub>) with some nitrogen, phosphorus and other nutrient requirements. Producing one tonne of algae requires 2 tonnes of CO<sub>2</sub> and 1 tonne of oxygen, which can be turned into approximately 3.5 barrels of biodiesel. The quantity of CO<sub>2</sub> emissions was 50 million tonnes per day that is not absorbed in oceans or forests. The rate is quite alarming if not addressed in shape of algae. The partial capturing and utilization of CO<sub>2</sub> by algae will meet 10% of the total biodiesel demand of 100 million tonnes per year by 2020. It will help restricting climate change as Algae-based fuel reduces 68% GHG emissions as compared to fossil fuels [24]; Equity Research Industry Report, 2009). Total production of 10,000 tonnes algae around the world has been reported in 2007. Half of it was contributed by china and most of the rest by Japan, Taiwan, United States, Australia, and India (Equity Research Industry Report, 2009).

The recent stories of success clearly hint flourishing algae industry on commercial basis in near future. Once become commercial, it is projected that the industry will be the world's largest industry due to addressing a wide range of peak oil, climate change, food prices, soil depletion and water shortages [24].

#### *Analysis of the Expected Sources of Revenue (Projected Revenue):*

##### *1). Revenue from Carbon Trading in Malaysia:*

Carbon capture and trading activities are yet to become common in developing countries including Malaysia [25]. The Managing Director and Head of Global Markets of Standard Chartered Bank Malaysia Bhd (StanChart) Mr. Sandeep Bahl said in May, 2008 that the country is expected to have a trade on account of carbon worth between RM 3.2 billion and RM 6.4 billion in next five years by 2013. A research by the Malaysia Energy Centre reports that Malaysia had a potential of 100 million tons of carbon and it could benefit from carbon trading by translating it into RM4.8 billion revenue. However, it was also reported that Carbon Trading might take another five years to get maturity in Malaysia and Asia-Pacific region [26]. The Prime Minister of Malaysia Datuk Seri Najib Razak stated on 16 December 2009 at UNFCCC Copenhagen that the Government is committed to reduce CO<sub>2</sub> emissions intensity of the country's Gross Domestic Product (GDP) up to 40 per cent by 2020 voluntarily [27] since Malaysia is the signatory of Kyoto protocol and listed in Non-Annex I. The government has already achieved 33% of this target set by 2020 in 2014 [28]. The Govt. is committed to convert the commitment into business opportunities [29]. What price of emitted CO<sub>2</sub> in Malaysia can we expect? The Australian Govt. rate of \$23 (AUD) per tonne CO<sub>2</sub> as announced on 1st July, 2012 for financial year 2012–2013 in Australia may be adopted. It is also premeditated to raise the rate 5% every year till 2015. Based on this, by taking time and currency conversion factor, a rate of RM 72.38 per tonne is calculated for Malaysia.

Looking another analysis for determination of price per tonne of emitted carbon in Malaysia, the paper focuses the "cap and trade" mechanism. The "cap" is a limit of the allowed quantity of pollution or released carbon dioxide of a corporation of industrialized country per year. The "trade" aspect controls this cap by "permits" that have monetary value. The corporations have to purchase these permits in the market to counter the excess of GHG emissions if they emit or pollute more than their permitted quota. The corporation can also earn by selling their permits if they emit less than their allocated quota. Thus the developing countries (where

there is no fixation of caps or low emission) have an opportunity to sell their permits to the corporations in developed countries (where corporations face these mandatory caps). On the basis of this economic charm, the Kyoto protocol has a target to bring the level of emission back to the level of 2005 by 2020. It is an emissions reduction of 1.74% annually and a total of 21% for meeting the level of 2005 by 2020. The current caps and trade of carbon trading had a worth of \$150 billion annually, where the price of one permit (granted on one tonne reduction of Co<sub>2</sub> emission) is \$ 21.81[30]. By converting the price into Ringgit Malaysia a rate of RM 70.23 per ton is calculated for Malaysia. The Malaysian economy can earn with this rate of per tonne reduction in Co<sub>2</sub> emissions.

## *2. Revenue from Carbon Tax:*

Despite the opposition of China, Russia and USA, who are large scale users of carbon for generating electricity to carbon tax, Europe is practicing carbon tax as a source of revenue. Many countries of the Europe like Denmark, Finland, Germany, Ireland, Italy, the Netherlands, Norway, Slovenia, Sweden, Switzerland and the UK have levied energy taxes on carbon content. However, the rate of carbon tax is not uniform in all sectors in none of these countries [31].

Finland was the first country to introduce carbon tax in 1990s followed by Netherland after levying the new tax at a rate of US\$20 per tonne CO<sub>2</sub> emissions. Sweden was the third country to levy the carbon tax at a rate of \$100 per ton in 1991 increased to \$150 later on in 1997. The UK also attempted implementation of the new tax in 1991, however couldn't prove successful due to lack of uniform political will. Republic of Ireland had a rate US\$20 per tonne of the tax [31]. It is estimated by the Government of Taiwan that the revenue from energy tax and carbon tax can be raised to US\$5.1bn and US\$7.3bn respectively on an annual basis by 2021, if implemented at a rate of US\$61 in 2009 [32].

## *Current status of Carbon Tax in Malaysia:*

Most of the Asian countries including china and Malaysia are still waiting and completing their paper work to be tabled for implementation of the tax. Budy Resosudarmo suggested that Carbon Tax should be levied on heavy industries but should not burden the lower income group in Malaysia [12]. The tax will be an effective mechanism to reduce carbon emissions and air pollution. The carbon tax is regressive, which will affect poor directly or indirectly, hence he proposed that 50 % of the revenue gained from the carbon tax should be used to subsidize the poor. On the other hand the industries that pay the tax should be given some tax relief. In the richer, but small countries such as Singapore and Brunei carbon tax doesn't matter much as there are less heavy industries using fossil fuels and fewer vehicles as compared to Malaysia. Dr Budy proposed that the tax should be levied at a rate of US\$10 per tonne of carbon emission. Companies embarking CCSU are exempted from paying the tax for the amount of carbon captured and stored, and this carbon tax saved can be considered as the revenue gain in carrying out CCSU [12].

## *1. Enhanced Oil Recovery:*

EOR use over 48 million metric tons (tonnes) of CO<sub>2</sub> per year. Out of which, about 25 percent (12 million tonnes) is anthropogenic (produced by human activities such as oil refining or fertilizer manufacturing) while the rest is extracted from natural deposits (Trinity 2006). The CO<sub>2</sub> used for EOR is a costly commodity; hence oil companies ensure that up to three quarters of CO<sub>2</sub> injected remains underground in the oil field. Despite the high cost of the technique, enhanced extracted oil is still profitable subject to the existing oil prices. In Canada, a CO<sub>2</sub>-EOR project has been established by Cenovus Energy at the Weyburn Oil Field in southern Saskatchewan since 2000. The project is expected to inject a net 18 million ton CO<sub>2</sub> and recover an additional 130 million barrels (21,000,000 m<sup>3</sup>) of oil. In addition, it will extend the useful life of oil field by 25 years [33].

The maturity of oil fields and hike in oil prices has made the technique more attractive and profitable for oil companies. The EOR has been used by oil and gas industry for the last 40 years. It has been reported that EOR projects produced 650,000 barrels of oil per day in 2006 (equal to 13% of total US production) (Moritis, 2006). The United States is leader in developing and using technologies for CO<sub>2</sub> EOR by performing approximately 96 percent of worldwide CO<sub>2</sub> EOR [34]. It has been reported that enhanced oil recovery technology yielded USD 38.1 billion in 2012 and projected to expand to USD 516.7 billion by 2023 in the USA. It is also anticipated that the US market for EOR will grow up to 26.7% by 2023 (Transparency Market Research, 2014).

## *EOR status and statistics in Malaysia:*

PETRONAS Executive Vice-President (Exploration and Production Business) Datuk Wee Yiau Hin said that 50 per cent of Malaysia's oil producing fields has EOR potential where 10 EOR projects are in progress at present. A budget of RM46 billion is approximated for the completion of these projects. The EOR will be implemented in phases in Malaysia hence will take ten years more. However, Malaysian oil reserves are maturing, which is alarming for the country to address the decline soon and properly. Subsequently, the EOR technology implemented at the Tapis oilfield, offshore Terengganu, and expected to be functional in current

year (2014). PETRONAS allocated RM1.1 billion till 2018 to increase production at maturing oilfields. The cost of RM10 billion is estimated to enhance oil production from 25,000 to 35,000 barrels per day by 2016–2017. The current figures are 3,000–4,000 barrels per day (The Malay Mail January 12, 2014). Malaysia can also look into the US experience for determining the associated costs and benefits of EOR. It has been reported that an additional oil ranging 0.1–0.5 ton is produced from one ton of CO<sub>2</sub>. If a price of \$ 45 per barrel is assumed the revenue from using EOR range from \$30 to \$150/tCO<sub>2</sub>[36].

#### 4. Algae Pricing or Expected Revenue from Algae:

A survey from the producers of Algae reported that 28% of producers use algae to produce fuels, 35% feeds, 28% nutritional products and 18% for producing fertilizers. The survey further reports that 70 % of respondents (producers) believe that algae-based fuels will compete fossil fuels by 2020. The results are quite consistent with that ABO survey in 2012 where 69 % of producers' responded the same. Around 64 % of the respondents (producers) reports that cost of algae based oil is \$5.00 or less per gallon [37].

According to Energy Information Administration (EIA) expected prices of fossil fuel in 2020 will be: jet fuel, \$123 per barrel or \$2.94 per gallon; gasoline, \$154 per barrel or \$3.69 per gallon; diesel, \$163 per barrel or \$3.89 per gallon. It can be treated as the prices of algae based oil in 2020, as it has been reported by the ABO survey 2013 that algae based oil will compete fossil oil by 2020 [38].

#### Algae in Malaysia:

In 2011, Tenaga Nasional Behad (TNB) in Malaysia started a laboratory based experimental cultivation of algae from captured CO<sub>2</sub> from the Sultan Azlan Shah power station in Lumut, Perak. The project has improved the experiences of how to isolate species, culture and monitor growth of algae, and designing of photo bioreactor. It is a proactive endeavor of TNB for controlling CO<sub>2</sub> emission in a sustainable way. However, the experiment is in an embryonic stage launched with RM 1 million and yet awaited large scale production till date [39]

The above discussed expected sources of revenue can be expressed in the following function;

$$Y = CTrdx + CTx + Algx + EORx + e$$

Where

Y = Expected revenue from CCSU

CTrdx = Revenue from carbon Trading

CTx = Revenue from carbon tax

Algx = Revenue from carbon Algae production

EORx = Revenue from enhanced oil Recovery (EOR)

e = Error term

#### Recommendations:

The UN policy and Kyoto protocol for mandatory GHG emissions should be further strengthened. This will lead to the adoption of CCSU practices and development of this new market.

The Government should subsidise the CCSU projects since the projects require huge investments. Moreover, the import duties and other taxes, on importing the cutting edge technology to capture and store CO<sub>2</sub> should be reduced.

The Government should implement carbon tax. The implementation of the tax will force corporations in reducing their emissions. The reduced level of carbon emission will facilitate carbon trading with other developed countries which face mandatory limits or quotas of carbon emissions.

More research studies should be conducted on cost and benefit analysis of CCSU as these will enhance the understanding and motivation of the investors, corporations and Governments in this newly emerged business market

The environmental protection laws and its implementation should be strengthened as that will encourage CCSU operations.

The proper and specific laws that regulate CCSU should be implemented. Moreover the development and implementation of laws protecting investors will improve the investment in CCSU projects.

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