A GRAPHICAL COST SCREEN TECHNIQUE FOR CARBON MANAGEMENT

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Dedicated to the gentle soul of my late father AlhajiAbdulkadir Oba Busari

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ABSTRACT

Research involving carbon management has received increased attention over the last decades, due to the threat posed by global warming and increases in the atmospheric Green House Gas (GHG) emission.Improving energy efficiency, use of renewable energy and carbon dioxide(CO_2) capture and storage are among the proposed method for carbon management in the industrial sectors.Previous researchers have used carbon emission pinch analysis (CEPA) techniques to plans for carbon emission in the industry. But the cost effectiveness of the techniques has not been verified.This research is aimed at developing a graphical cost-screening technique for the CO_2 emission reduction planning in an industrial site.This method employs the carbon management hierarchy (CMH) as a tool to guide CO_2 emission reduction planning. It also extends the Systematic Hierarchical Approach for Resilient Process Screening (SHARPS) graphical cost-screening technique that was developed for water system to guide and screen design options involving process changes in order to obtain a cost effective system that meets a given CO_2 emission targets.Application of the SHARPS screening techniques has successfully achievedthe final cost effective minimum CO_2 emission target for a stationary site with TPP_{set} (Total payback period set by designer) of 2 years, targeting 29.12 tons/hr of fresh CO_2 and 16.74 tons/hr of CO_2 emission prior to design. Using the predesign cost estimate method, the system needs approximately a net capital investment of USD 556.21 million,to give a net annual savings of USD 333.7 million with a total payback period of approximately 18 months.

ABSTRAK

KajianmelibatkanpengurusanKarbontelahmenerimaperhatian yang meningkatsejakbeberapadekad, berikutandaripadaancaman yang ditimbulkanolehpemanasan global danpenigkatanpembebasan Gas RumahHijauatmosfera.Meningkatkankecekapantenaga, penggunaantenagabolehdiperbaharuidanpenangkapan CO_2 danpenyimpananadalahantarakaedah yang dicadangkandalam sector industri.Penyelidik yang terdahulutelahmenggunakankaedahAnalisa ‘Picit’ PembebasanKarbon (CEPA) untukmerancangpembebasankarbondalamindustri.Namun, kecekapankostekniktersebuttidakdisahkan.Kajianinibertujuanmembinasatukaedahgrafikpenyaringankosuntukperancanganmengurangkanpembebasan CO_2dalamtapakindustri. Kaedahinimenggunakanhierarkipengurusankarbonsebagaialatpanduandalamperancanganmengurangkanpembebasan CO_2.IajugamemanjangkanteknikgrafikpenyaringankosPendekatanHierarkiSistematik untukPenyaringan Proses BerdayaTahan (SHARPS) yang telahdibinauntuksistem air untukpanduandanpilihanrekabentukpenyaringanmelibatkanperubahan proses untukmencapaisatu system koscekap yang memenuhi target pembebasan CO_2 yang ditetapkan. Aplikasitekniksaringan SHARPS telahmencapaikecekapankos minima target pembebasan CO_2akhirbagitapaktetapdengan TPPset (Jumlahtempohpulangan yang ditetapkanolehpereka) 18 bulan, menyasarkan 29.12 tan/jam CO_2barudan 16.74 tan/jam pembesan CO_2sebelumrekabentuk. Menggunakanrekabentukawalbagiteknikanggarankos, system inimemerlukananggaranpelaburan modal bersihsebanyak USD 556.21 juta, untuk member simpanantahunanbersihsebanyak USD 333.7 jutadenganjumlahtempohpulangankira-kira 18 bulan.

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LIST OF ABBREVIATIONS

BOM	Bill of material
CCS	Cost of carbon capture and storage
CDM	Clean development mechanism
CEMCN	Cost effective minimum CO_2 emission network
CEPA	Carbon emission pinch analysis
CEMWN	Cost effective minimum water network
EFW	Energy from waste
FCO_2	Flow rate of CO_2 emission
FOG	Flow rate of other gases
GHG	Greenhouse Gas emission
MCE	Minimum CO_2 emission
MILP	Mixed integers linear programming
MWR	Maximum water recovery
NAD	Network allocation diagram
NAS	Net annual savings
NCI	Net capital investment
SHARPS	Systematic Hierarchical Approach for ResilienceProcess Screen.
TP	Total payback period
TPP_{set}	Total payback period set by design
USD	US Dollar
VSD	Variable speed drive

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Awareness of rising carbon dioxide (CO_2) emission and possible ways to reduce them has captured the attention of the industrial sector. An increasing number of environmental, political, and social drivers are placing pressure on industry to determine the most viable and cost effective measures to limit their impact on climate change. Power generators are the highest point source emitters of CO_2 and will be among the most affected by future climate change regulations. Other industries like petroleum refining, cement production and steel manufacturing will likely need to adapt CO_2emission management in future decisions and operation strategies.

Masjuki *et al.* (2002) explained emission as a process of energy utilization especially the emissions trial activities produced a huge effect on the environment that influences human health, organization growth, and climatic changes. In the near future, the energy consumption is expected to rise especially in developing countries, this is as a result of the rapid transformation in the industrial sector in recent times which consequently lead to massive release of pollutant to the environment causing harmful effect on environment and human health(Oh, 2010). The major increase in GHG is attributed largely to CO_2 emission as the main gas leading to global warming and climate changes.

Saboori*et al.* (2012) reported that, greater average air and ocean temperatures, extended melting of snow and ice and rising global average sea level are some profound proofs of global warming. IPPC(2007) predicted the rise in the global temperature and sea level of between 1.1^{o} C to 6.4^{o} C, 16.5cm to 53.8cm respectively by 2100.The amount of world energy demand contributed by fossil fuel is greater than 80% of the world energy demands are from fossil fuel which gives rise to increases in CO_2 concentration in atmosphere and contribute to global warming. CO_2 emission coefficients for various sources and corresponding energy conversion units are presented in Table 1.1.

Table 1.1 : Carbon emission coefficients for different fuel sources and energy conversion units. (Adapted from Bouste*et al.,* 1979;Fluck 1992).

Fuel (source/ energy unit)	Equivalent carbon emission (kgCE)
One kg of fuel	
Diesel	0.94
Coal	0.59
Gasoline	0.85
Oil	1.01
LPG	0.63
Natural gas	0.85
Units	
Million calores(mcal)	93.5×10^{-3}
Gigajoule	20.15
BTU	23.6×10^{-6}
Kilowatt hour (kWh)	7.25×10^{-2}
Horsepower	10^{-2}

The research involving carbon management has received increased attention over the last decades, due to the threat posed by global warming and increases in the atmospheric GHG emissions. Improving energy efficiency, use of renewable energy, and CO_2 capture and storage are among the proposed methods for carbon management in the industrial sector. Figure 1.1 shows the typical carbon management principles for measuring (Greenhouse gas) GHG emissions. The principles set out a framework for measuring GHG emissions. In practise, the framework can be applied through an iterative process. Depending on how far advance the industrial sector is in managing CO_2 emission. The first cycle through the principles may just enable identification of opportunities for CO_2 emission management. The second cycle can then be used to confirm objective and develop a strategy that optimizes CO_2 emission management.

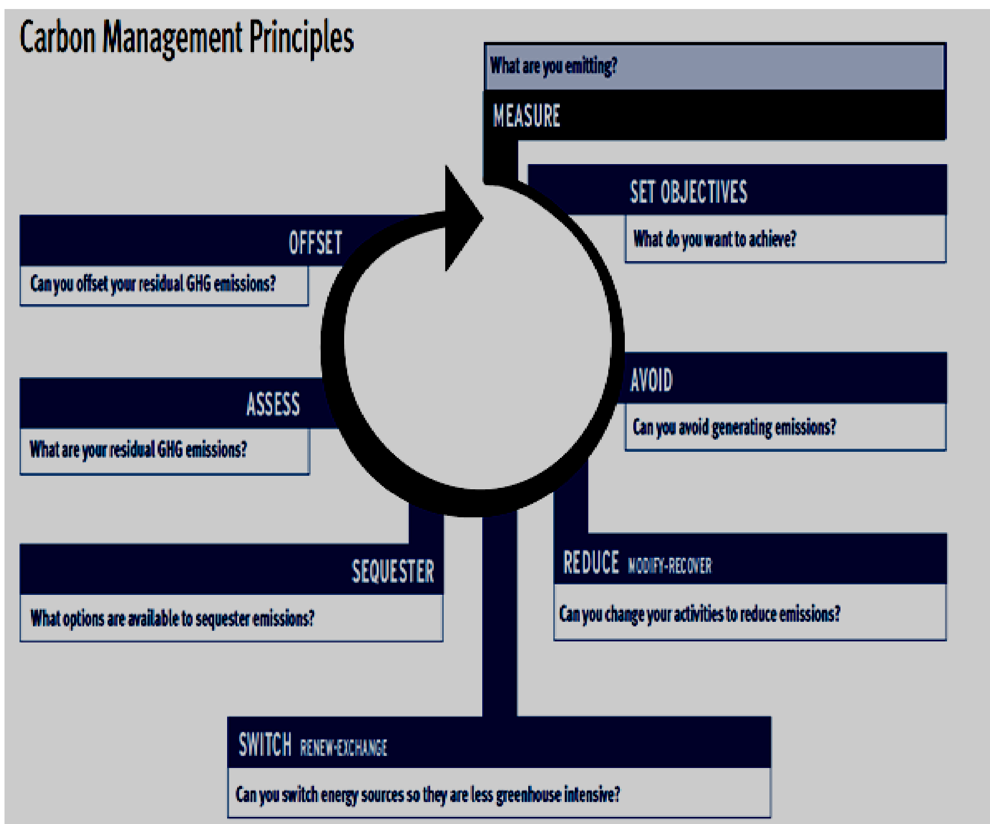

Figure 1.1 Carbon management principle frame work for measuring GHG emission (EPA, 2007)

Munir *et al.*(2012) have established a viable tool through the use of process integration to reduce amount of CO_2 emission released to the atmosphere from industrial site and contributed to the emission reduction target. The aim of this work is to apply SHARPS techniqueas a cost-screen tool guided by CMH to graphically design a cost effective minimum CO_2 emission target for an industrial site subjected to a desire payback period.

1.2 Research Background

Carbon management involves the measurement and management of the six greenhouse gases that are covered under the Kyoto protocol. The increasing concentration of GHG emission such as carbon dioxide (CO_2), methane(CH_4), nitrous oxide (N_2O), sulphur hexafluoride (Sf_6), Hydro fluorocarbons (HFCS), and Perfluoro carbons (PFCS) in the atmosphere is acting to trap heat radiation from the Earth`s surface and is raising the surface temperature of the Earth (Dincer, 1998). The figure 1.2 showed a schematic representation of this global climate change problem.

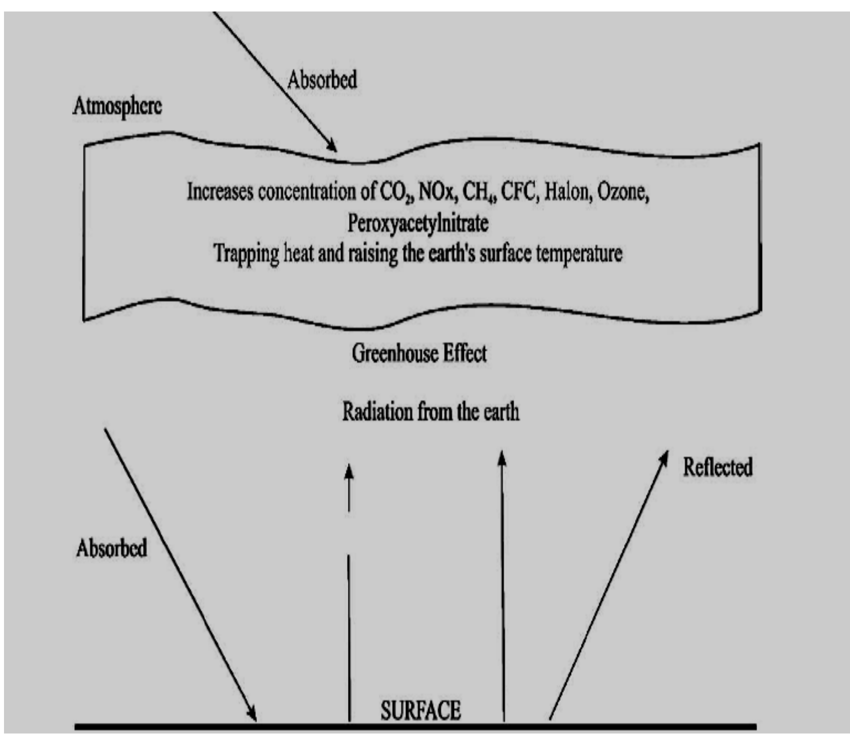

Figure 1.2 A schematic illustration of GHG effect (Dincer, 2000)

The principal gas leading to increases in GHG is CO_2that attributed to the global warming and climate changes (The World Bank, 2007).The transformation of the economy from agriculture based to industrial level over the last three decades has elevated Malaysia to be the highest emitter of CO_2 among the South East Asian countries (Muis*et al.,* 2010). There is a 221% increases in CO_2 emission in Malaysia from 1990 – 2004 (Muis*et al.,* 2010). This has called the attention of Malaysia government to intensify their effort to reduce the CO_2 emission by 40% from 2005 level by2020 subjected to financial aids from developing countries. The pledge was made in 2009 at the UN conference of parties in Copenhagen, Denmark by the Prime MinisterDatuki Seri NajibTunRazak.(Malaysia Digest.com 2009).

There have been extensive works on the best approaches to drastically minimize the amount of CO_2emission from industrial process to achieve CO_2 emission reduction targets and reduce the impact of CO_2 emission on climate change.The work of (Park *et al*., 2009) investigated the possibility of reducing CO_2 emissions in Korean petroleum refinery through the new energy saving technology and CO_2 mitigation. The work used five new technologies, which are Hybrid SD-Leap Mode, Crude Oil Distillation Unit (CDU),Light Gas Oil Hydro sulfurization Unit (LGO HDS), Vacuum Residue Hydro-Desulfurization (VR HDS) Process. Theenergy consumption and CO_2 emission of the nation, particularly from the industrial sector were estimatedusing the hybrid SD-LEAP model.The model predicted that, in the year 2030 the new technologies will cause 0.048% CO_2 reduction nationally and 0.109% reduction in the industrial sector. (Munir*et al.*2012) introduced a holistic CO_2 emissions planning framework based on the Pinch Analysisgraphical approach for CO_2 emission reduction. They plotted CO_2 source against CO_2 demands, and investigated some process modification options that can lead to CO_2 emission reduction targets for an industrial site.

This study extended the application of SHARPS technique as a cost screening tool to achieve the cost effective minimum CO_2 emission reduction target, considering all the process modifications guided by CMH. The net capital investment

(USD) will be plotted against the net annual savings (USD/yr). The slope of the plots represents the payback period for each process modification options.

1.3 Problem Statement

Over the past decades the main concern has focused on “end of pipe” treatment as an approach for CO_2 emission reduction such as CO_2 capture and storage (CCS), CO_2 injection in enrich oil recovery (EOR) among others. CO_2 emission reduction by process integrationbased on the Pinch Analysis approachlaterbecomespopular, being a viableinsight-based technology for CO_2 emission planning and reduction that is easy to understand and apply. Alongside development of the insight-based approaches, several works on CO_2 emission planning and minimisation using the mathematical programming approach have emerged. The mathematical techniques are however typically rigorous, and the mathematical equations are not easy to set up. This makes them less popular especially among the industrial practitioners. In this work the SHARPS technique has been extended as a costing tool to design a system to achieve the cost effective minimum CO_2 emission. The total payback period will be obtained by plotting net capital investment (USD) against the net annual savings (USD/yr) covering all levels of the carbon management hierarchy (CMH), SHARPS allow the total payback period to be evaluated subject to the desired payback period set by a designer. The problem statement can then be summarized as;

Given a process plant with several sources of CO_2 emission, it is desired to design a system to achieve the cost effective minimum CO_2 emissions for an industrial plant using the extended Systematic Hierarchical Approach for Resilient Process Screening (SHARPS) technique. SHARPS will be used to screen cost-effective process modification options that will be explored using carbon management hierarchy as a guide subject to a desired payback period set by a designer.

1.4 Objective of Study

The objective of this research work is to extend the application SHARPS graphical cost-screening tool that was developed for water system, and adopt it as a cost-screening tool to achieve a cost effective minimum CO_2 network design guided by CMH in the process changes.

1.5 Scope of Study

At the end of the study, a graphical cost-screen technique for carbon management will be developed by extending the SHARPS graphical cost-screen tool that was developed for water system. Tasks to be accomplished for achievement of study objectives include:

- Data collection which includes flow rate and concentrations of sources of gas streams containing CO_2, then flow rates and concentrations of CO_2 demand streams.
- Extend the application of SHARPS graphical cost-screening tool for carbon emission planning. It can be achieved by plotting the net capital investment (USD) against the net annual saving covering all CMH. The gradient of the plot represent the payback period for process changes. The steepest positive gradient shows the most expensive scheme per unit CO_2 emission reduction. The total payback period will also be obtained by draw a straight line connecting the starting point and end at the end point of the IAS plot.
- The case study application of the graphical cost effective minimum CO_2 emission network design is still using the same case study of previous work of (Munir*et al.* 2012).

1.6 Significant of study

The main contribution of this study is toextend the application of SHARPS graphical cost-screen tool used in water management system and adopt it to achieve a graphical cost effective minimum CO_2 emission network design for an industrial site.

1.7 Outline of the dissertation

This research projectdissertation consists of six chapters. **Chapter 1** gives an overview of global and local CO_2 emission management issues, problem statement, objective and scope of the study which aim at extend the application of SHARPS technique as a costing tool for cost effective minimum CO_2 emission reduction target network design.

Chapters 2 Provide a literature review presented in this work. The development of research on CO_2 emission reduction target and network design techniques using mathematical programming, optimal planning system, and pinch analysis are reviewed. The cost of CO_2 capture is also discussed in this chapter.

Chapter 3 Presents a detail methodology of this study to achieve the research objective. It consists of the technique to design a cost-effective minimum CO_2 emission reduction network to achieve a desired payback period set by a designer or plant owner.

Chapter 4 Presents the discussion of the results on implementation of the developed methodology.

Chapter 5 presents the conclusion and recommendation part of the work.

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