DEVELOPMENT OF REAL TIME CARBON EMISSIONS AND ENERGY MONITORING SYSTEM FOR INDUSTRIAL ENVIRONMENT USING OPC ARCHITECTURE

MOHD FAIZ BIN ROHANI

UNIVERSITI TEKNOLOGI MALAYSIA

DEVELOPMENT OF REAL TIME CARBON EMISSIONS AND ENERGY MONITORING SYSTEM FOR INDUSTRIAL ENVIRONMENT USING OPC ARCHITECTURE

MOHD FAIZ BIN ROHANI

A project report submitted in fulfilment of the
requirements for the award of the degree of
Master of Science (*Computer System Engineering*)

Advanced Informatics School
Universiti Teknologi Malaysia

MAY 2016

To my beloved mother, wife and family..

ACKNOWLEDGEMENT

First and foremost, I would like to express my greatest appreciation to my supervisor, Dr Noor Azurati Ahmad@Salleh for her precious guidance and encouragement during completion of my project. Even though she was busy with her daily tasks, she was always there to offer assistance and helping me with my project. Without her continual support and advice, this project would have not possible to be accomplished. I would also like to thanks to Dr Hairi, Dr Wira Jazair Yahya and En Hasanudin of MJIIT for giving me the opportunities doing the testing in their Diesel Engine Testing laboratory.

I owe my loving thanks to my family for supporting me spiritually and financially throughout my life. Without their encouragement and understanding it would have been impossible for me to finish this project.

Last but not least, I offer my regards and blessings to all of those who supported me in any respect during the completion of this project.

ABSTRACT

Global warming is referred to the rise in average surface temperatures on earth primarily due to the Greenhouse Gases (GHG) emissions, such as Carbon Dioxide (CO_2) which trapped the heat within the atmosphere that will affect the ecosystems. Monitoring the emissions, either direct emissions from industrial processes or indirect with electrical energy consumptions is important to control or to minimize their impact to the environment. Electricity generation is normally using the steam turbine that burning fossil fuel as the source of energy, thus releases CO_2 in the process. Most of the existing environment monitoring system is being designed and developed for non-industrial environment monitoring. Hence, the aim of this project is to develop industrial CO_2 emissions monitoring system that can monitor real-time emissions in the industrial plant as well as energy usage which can be translated to its CO_2 equivalent. Developed using real-time development methodologies, the system implement Object Linking and Embedding for Process Control (OPC) communication protocol that widely used in process and control applications in the industry today. The protocol is successfully being interfaced to a low power Arduino microcontroller, hence it able to provide the sensor data to any of existing industrial OPC compliant Supervisory Control and Data Acquisition (SCADA) system, for real-time emissions monitoring**.** The system has been successfully tested in Vehicle Engine Testing Lab in MJIIT, UTM which providing the suitable environment for real-time CO_2 emissions measurement. The measurement data has been showed in an industrial SCADA application developed for the project. The system should benefits the industries in monitoring and managing their real-time carbon emissions which can be interfaced to their existing process monitoring system.

ABSTRAK

Pemanasan global adalah berpunca daripada kenaikan suhu permukaan purata di bumi terutamanya disebabkan oleh Gas Rumah Hijau (*Green House Gases*, GHG), seperti karbon dioksida (CO_2) yang telah memerangkap haba dalam atmosfera yang akan memberi kesan kepada ekosistem. Pemantauan sama ada pengeluaran langsung daripada proses industri atau tidak langsung dengan penggunaan tenaga elektrik adalah penting untuk mengawal atau mengurangkan kesannya kepada alam sekitar. Penjanaan elektrik biasanya menggunakan turbin stim yang membakar bahan api fosil sebagai sumber tenaga, dengan itu akan mengeluarkan CO_2 dalam proses penghasilannya. Kebanyakan sistem pemantauan alam sekitar yang sedia ada direka dan dibangunkan untuk pemantauan alam sekitar bukan perindustrian. Oleh itu, tujuan projek ini adalah untuk membangunkan sistem pemantauan yang boleh memantau pelepasan karbon secara masa nyata di dalam loji perindustrian serta penggunaan tenaga yang boleh diterjemahkan kepada jumlah pelepasan karbon. Dibangunkan menggunakan metodologi pembangunan masa nyata, sistem menggunakan protokol komunikasi *Object Linking and Embedding for Process Control* (OPC) yang digunakan secara meluas dalam aplikasi proses dan kawalan di industri hari ini. Protokol berjaya di antaramuka dengan mikropengawal Arduino kuasa yang rendah, yang dapat menyalurkan data kepada mana-mana sistem kawalan industri seperti *Supervisory Control and Data Aquisition System* (SCADA), untuk memantau pelepasan karbon secara masa nyata. Sistem ini telah berjaya diuji di dalam makmal ujian enjin kenderaan di MJIIT, UTM yang menyediakan persekitaran yang sesuai untuk pengukuran pelepasan CO_2. Data pengukuran telah ditunjukkan pada antaramuka sistem yang dibangunkan khas untuk projek tersebut. Sistem ini memberi manfaat kepada industri memantau dan menguruskan pengeluaran karbon yang boleh di antaramuka kepada sistem pemantauan proses sedia ada.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

APN	Asia Pacific Network for Global Change Research
ARM	Advanced Risc Machine
CO_2	Carbon Dioxide
COM/DCOM	Component Object Model/Distributed
DSSS	Direct Sequence Spread Spectrum
EEPROM	Electrically Erasable Programmable Read Only Memory
GHG	Green House Gases
GPRS	Global Packet Radio Service
GSM	Global System for Mobile Communications
HMI	Human Machine Interface
HVAC	Heating, Ventilation, andAir Conditioning System
I^2C	Inter Integrated Circuit
IOT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
ISM	Industrial, Scientific and Medical Band
LCI	Low Carbon Initiative
MJIIT	Malaysia-Japan International Institute of Technology
NDIR	Non Dispersive Infra-Red
OPC	Object Linking and Embedding for Process Control
OPC A&E	OPC Alarm and Events
OPC DA/HDA	OPC Data Access/Historical Data Access
OPC UA	OPC Unified Arichitecture
RAM	Random Access Memory
RF	Radio Frequency
RISC	Reduced Instruction Set Computing

SCADA	Supervisory Control and Data Aquisition
SDLC	System Development Life Cycle
SDRAM	Synchronous Dynamic RAM
SMS	Short Message Service
SPI	Serial Peripheral Interface
USB	Universal Serial Bus
UTM	Universiti Teknologi Malaysia
WSN	Wireless Sensor Network

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

The earth climate system is continuously evolving; with part of it is caused by human activities that resulting in emissions of Greenhouse Gases (GHG) such as carbon dioxide, methane and many other gases which leading to global warming. According to the Inter-Government on Climate Change (IPCC), global warming is the increase of Earth's average surface temperature due to effect of GHG from burning fossil fuels or from deforestation, which trap the heat that would otherwise escape from earth. One of the GHG emissions that contributing the most to global warming is Carbon Dioxide (CO_2). Carbon dioxide has contributed 65% of total emissions by gases as showed in the following Figure 1.0. Hence, monitoring and managing carbon emissions are important to reduce its impact on the environment.

Industrial processes and electricity production has contributed 21% and 25% globally as shown in Figure 1.0. Industrial and manufacturing processes with the use of heavy industrial equipment’s are known to generate carbon emissions and electrical energy (which indirectly contribute to carbon emissions) usage is normally huge. Control of these emissions, by monitoring of carbon level and energy use of the equipment's is equally important. Current concerns regarding the manufacturing processes are not limited to the production quality concern, but also considering the ecological footprint. As a result, new systems aimed at measuring the eco-efficiency and environmental impact of each manufacturing process in a production system (Victor and Federico, 2014).

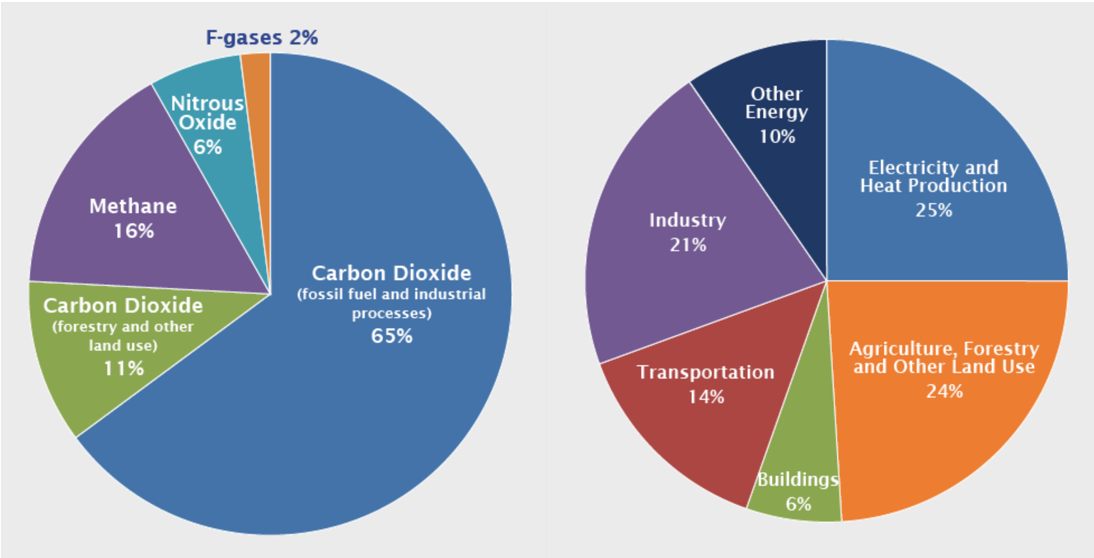

Figure 1.1: World Total GHG Emissions by Gases and Industry (Source: IPCC (2014))

A real-time system that could monitor the releases of carbon is needed in order to achieve a low carbon emissions target. There is a lot of study on monitoring carbon and other gases emissions, which using a different implementation. Among all, Mihajlovic et al. (2012) studies the landfill gases emissions particularly CO_2 and Methane, but for monitoring purposes only. While Garcia et al. (2012), present a conditioning system for low cost non-dispersive infrared gas sensors used to measure the CO_2 concentration in the open environment. Victor and Federico (2014), study the wireless sensor network to monitor the carbon emission level. They have used standard communication protocol, as an integration tool to interface to another generic system. They are focusing on the wireless sensor network topologies and power efficiency requirement of the wireless node.

The current project is focusing on real-time monitoring of carbon level in an industrial area, release by the manufacturing processes or from another source of emissions. Besides that, the level of electrical energy usage is high due to industrial process equipment's high power consumption. It is important to have a good idea of the carbon emission level capture by the sensor in the manufacturing area as well as energy consumption of the equipment's. The data can be brought to the plant control system for monitoring and analysis purposes. The system will open the way for future device control by utilising the standard industrial communication protocol widely used today, such as the Industrial Ethernet and the Object Linking and Embedding for Process Control (OPC). In industrial plant area, the sensors placement and their interconnection cannot be resolved using cables and wiring due to physical restriction in the area. As such, this project proposed a Wireless Sensor Network (WSN) solution to solve the problem installing the system in the industrial areas.

1.2 Background of Problem

Global warming is a renowned environmental problem and it certainly requires tools to monitor the phenomena which cause the increase of GHG concentration in the atmosphere. Human activities that are resulting in emissions of GHG contribute to these problems. These gases will trap the heat in the atmosphere that causes the rising of earth temperature. The GHG that causes the rising of earth temperature is highly contributing by the Carbon Dioxide (CO_2). Therefore, the detection and quantitative measurement of GHG emissions are necessary as a means of monitoring the releases of GHG emissions, which bring bad impact such as dangerous weather patterns leading to natural disasters these days (Abdullah et al., 2012). Besides emissions from direct sources, fugitive emissions are emissions of gases or vapors from pressurized equipment due to leaks and other unintended or irregular releases of gases, mostly from industrial activities (IPCC, 2014). Carbon emissions need to be controlled because its effect on the environment requires special attention. In industry, especially in manufacturing processes and the huge electrical energy used, the emissions are inevitable. The sources of emission need to be identified; hence, proper action can be taken. This normally requires real-time processes data, which give a clue how the emissions are generated from the certain processes, and appropriate action to reduce it. It can be done with or without human intervention by a real-time system, hence, perform the required action based on the emissions data.

Industrial and Energy sectors contribute to massive GHG emission sources. This is due to the increment of industrial activities and energy demands of the sector and dependency on fossil fuel for electricity generation (Kuri and Li, 2009). Malaysian total CO_2 emissions come from energy consumption has increased dramatically over the past decade as can be seen in Figure 1.1 below. Hence, monitoring and measuring of energy consumption and release of GHG emissions are important to ensure that carbon emissions are monitored closely. The data can be analysed to find the root cause and historical trending of emissions thus facilitates the decision making in controlling the GHG parameters (Oh and Chua, 2010).

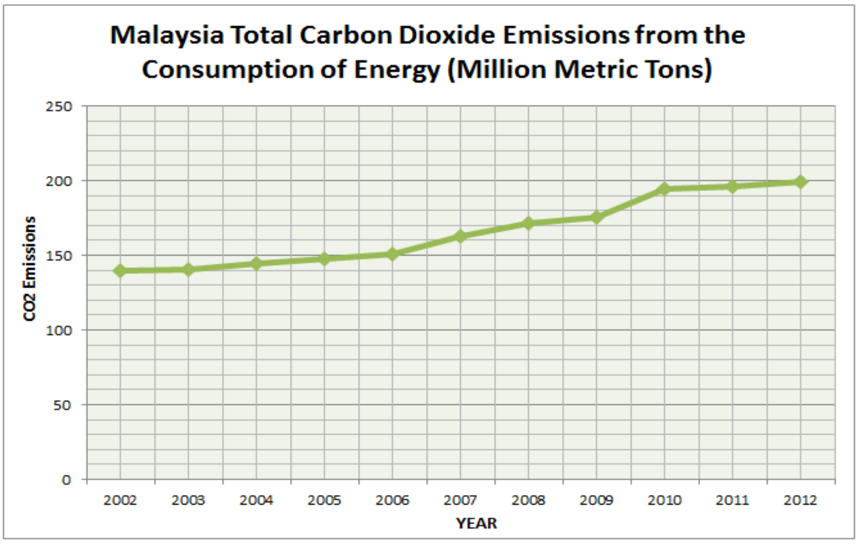

Figure 1.2: Malaysia Total Carbon Dioxide Emissions from Consumption of Energy

1.3 Problem Statement

Most of the related research monitoring system is not primarily being designed for the environment such as in the industrial area, and sensor networks are hard to be expanding. Furthermore, the lack of energy efficiency of the system could shorten sensor nodes operationality in the remote area. This project solved the problem highlighted above with a suitable low power consumption embedded system, and a scalable wireless sensor network for environmental parameters, especially CO_2. With the industrial area as target environment, the system will be deployed using a wireless technology such as ZigBee that has good performance in harsh and potentially damaging conditions including extreme temperatures and temperature cycles, ingress of particulates, electrostatic discharge (ESD), electromagnetic interference (EMI), vibrations, and physical impact.

The system has the capability to read real-time environment carbon emissions and interface the data to a multi-range of systems such as building control system through the use of Object Linking and Embedding for Process Control (OPC) protocol. This will allow the data such as energy consumption will be able to be extracted from the systems for the purpose of monitoring the energy usage and its carbon emissions equivalent. Monitoring the energy consumptions is equally as important as monitoring the real-time emissions because of the total carbon emissions from the said source has increased dramatically through its dependency on fossil fuel on electricity generation (Kuri and Li, 2009; Oh and Chua, 2010).

1.4 Project Aim

This project aims to develop and interface an embedded microcontroller system with wireless sensor network for CO_2, methane, propane (GHG gases) to existing industrial monitoring system. This will allow easy development using available system in-place, such as a Supervisory Control and Data Acquisition System (SCADA) for monitoring purposes. The project will measure real-time GHG emissions level and machinery energy power consumptions, especially CO_2 at the area under study.

1.5 Project Objective

The project has the following objectives:

i) To develop an embedded system for wireless CO_2 and energy consumption monitoring system.
ii) To integrate the system with industrial systems and application using Object Linking and Embedding for Process Control (OPC) protocol and architecture
iii) To test the system using a Supervisory Control and Data Acquisition System (SCADA) application to display the real-time and historical data analysis of carbon emissions and energy consumptions.

1.6 Research Question

i) What approach are available for embedded system for carbon emissions and energy consumptions monitoring ?

ii) What are the suitable hardware (sensors, wireless model and controller) and software architecture suitable for data gathering and sending in the sensor network?

iii) How to test the CO_2 emissions level and energy consumptions monitoring system in a real environment?

1.7 Project Scope

The main deliverable for the project is a carbon emission monitoring system. Therefore, the scope of this project is focused on:

i) Using Arduino based controller and ZigBee wireless protocol for wireless sensor networks.

ii) Real-time monitoring application for carbon emissions and electrical energy consumption, hence its equivalent carbon emissions.

iii) Using OPC integration between Arduino controller and SCADA industrial application.

1.8 Significance of Project

The project will provide another solution for carbon emissions and energy consumptions monitoring for the industrial environment. By having a controller that can be integrated into the existing SCADA industrial process monitoring system, it will much easier to implement the carbon monitoring in the plant floor. Minimal changes are needed for the SCADA system, and carbon emissions monitoring data can be right away being displayed at a low implementation cost.

1.9 Summary

This chapter provides a general outline of the project which is real-time carbon emissions and energy monitoring system brief introduction. The project background and problem statement has been identified, as well as the project aim and scope being figured out. In the next chapter, the literature review of the project and previous project approaches will be studied. The methodologies and techniques will be discussed in the next chapter for investigating the accurate approach for the carbon emissions and energy monitoring system in the real environment.

REFERENCES

Abdullah, A. ; Sidek, O.; Amran, N.A.; Za'bah, U.N.; Nikmat, F.; Jafar, H.; Hadi, M.A., "Development of wireless sensor network for monitoring global warming," in Advanced Computer Science and Information Systems (ICACSIS), 2012 International Conference on , vol., no., pp.107-111, 1-2 Dec. 2012

BeomJin Kang; DaeHeon Park; KyungRyung Cho; Changsun Shin; SungEon Cho; JangWoo Park, "A Study on the Greenhouse Auto Control System Based on Wireless Sensor Network," in Security Technology, 2008. SECTECH '08. International Conference on , vol., no., pp.41-44, 13-15 Dec. 2008

Chun-Yi Liu; Cheng-Long Chuang; Chia-Pang Chen; Wan-Yi Chang; Jyh-Cheng Shieh; Cheng-Han Lin; Chwan-Lu Tseng; Joe-Air Jiang, "Development of an embedded system-based gateway for environmental monitoring using wireless sensor network technology," in Sensing Technology (ICST), 2011 Fifth International Conference on , vol., no., pp.544-548, Nov. 28 2011-Dec. 1 2011

Dunfan Ye; Daoli Gong; Wei Wang, "Application of wireless sensor networks in environmental monitoring," in Power Electronics and Intelligent Transportation System (PEITS), 2009 2nd International Conference on , vol.1, no., pp.205-208, 19-20 Dec. 2009

Escorza, V.A.; Guedea, F., "A Wireless Sensors Network Development for Environmental Monitoring Using OPC Unified Architecture in a Generic Manufacturing System," in Mechatronics, Electronics and Automotive Engineering (ICMEAE), 2014 International Conference on , vol., no., pp.187-192, 18-21 Nov. 2014

Feng, A.; Knieser, M.; Rizkalla, M.; King, B.; Salama, P.; Bowen, F., "Embedded system for sensor communication and security," in Information Security, IET , vol.6, no.2, pp.111-121, June 2012

Fernbach, A.; Granzer, W.; Kastner, W., "Interoperability at the management level of building automation systems: A case study for BACnet and OPC UA," in Emerging Technologies & Factory Automation (ETFA), 2011 IEEE 16th Conference on , vol., no., pp.1-8, 5-9 Sept. 2011

Garcia-Romeo, D.; Fuentes, H.; Medrano, N.; Calvo, B.; Celma, S.; Antolin, D., "An electronic interface for measuring CO2 emissions in embedded systems," in Instrumentation and Measurement Technology Conference (I2MTC), 2012 IEEE International , vol., no., pp.417-420, 13-16 May 2012

Hadlich, T., "Providing device integration with OPC UA," in Industrial Informatics, 2006 IEEE International Conference on , vol., no., pp.263-268, 16-18 Aug. 2006

Herrera-Quintero, L.F.; Macia-Perez, F.; Ramos-Morillo, H.; Lago-Gonzalez, C., "Wireless Smart Sensors Networks, systems, trends and its impact in environmental monitoring," in Communications, 2009. LATINCOM '09. IEEE Latin-American Conference on , vol., no., pp.1-6, 10-11 Sept. 2009

Hesong Huang; Hongning Bian; Shuchuan Zhu; Jibo Jin, "A Greenhouse Remote Monitoring System Based on GSM," in Information Management, Innovation Management and Industrial Engineering (ICIII), 2011 International Conference on , vol.2, no., pp.357-360, 26-27 Nov. 2011

Irmak, E.; Bulbul, H.I.; Kose, A.; Calpbinici, A., "A web-based real-time industrial energy monitoring system," in Power Engineering, Energy and Electrical Drives (POWERENG), 2013 Fourth International Conference on , vol., no., pp.1713-1716, 13-17 May 2013

Jongwon Kwon; Gwanghoon Ahn; Gyusik Kim; Jo Chun Kim; Hiesik Kim, "A study on NDIR-based CO2 sensor to apply remote air quality monitoring system," in ICCAS-SICE, 2009 , vol., no., pp.1683-1687, 18-21 Aug. 2009

Kuri, B.; Li, F., "Allocation of emission allowances to effectively reduce emissions in electricity generation," in Power & Energy Society General Meeting, 2009. PES '09. IEEE , vol., no., pp.1-8, 26-30 July 2009

Manes, G.; Fantacci, R.; Chiti, F.; Ciabatti, M.; Collodi, G.; Di Palma, D.; Manes, A., "Enhanced System Design Solutions for Wireless Sensor Networks applied to Distributed Environmental Monitoring," in Local Computer Networks, 2007. LCN 2007. 32nd IEEE Conference on , vol., no., pp.807-814, 15-18 Oct. 2007

Manes, G.; Fantacci, R.; Chiti, F.; Ciabatti, M.; Collodi, G.; Di Palma, D.; Manes, A., "Enhanced System Design Solutions for Wireless Sensor Networks applied to Distributed Environmental Monitoring," in Local Computer Networks, 2007. LCN 2007. 32nd IEEE Conference on , vol., no., pp.807-814, 15-18 Oct. 2007

Mihajlovic, Z.; Milosavljevic, V.; Maodus, N.; Rajs, V.; Slankamenac, M.; Zivanov, M., "System for monitoring concentration of NO2 and CO gasses on landfill sites," in MIPRO, 2012 Proceedings of the 35th International Convention , vol., no., pp.183-186, 21-25 May 2012

Nikhade, S.G.,"Wireless sensor network system using Raspberry Pi and zigbee for environmental monitoring applications," in Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM), 2015 International Conference on , vol., no., pp.376-381, 6-8 May 2015

Rodriguez, M.G.; Ortiz Uriarte, L.E.; Yi Jia; Yoshii, K.; Ross, R.; Beckman, P.H., "Wireless sensor network for data-center environmental monitoring," in Sensing Technology (ICST), 2011 Fifth International Conference on , vol., no., pp.533-537, Nov. 28 2011-Dec. 1 2011

Schwarz, M.H.; Borcsok, J., "A survey on OPC and OPC-UA: About the standard, developments and investigations," in Information, Communication and Automation Technologies (ICAT), 2013 XXIV International Symposium on , vol., no., pp.1-6, Oct. 30 2013-Nov. 1 2013

Shaik, M.I., "Design & implementation of ARM based data acquisition system," in Electronics, Communication and Computing Technologies (ICECCT), 2011 International Conference on , vol., no., pp.38-42, 12-13 Sept. 2011

Shiwei Zhang; Haitao Zhang, "A review of wireless sensor networks and its applications," in Automation and Logistics (ICAL), 2012 IEEE International Conference on , vol., no., pp.386-389, 15-17 Aug. 2012

Su Wei; Fan Tongshun; Liu Ying, "Software Interface Technology of Intelligent Building System Integration," in Computing, Communication, Control, and Management, 2008. CCCM '08. ISECS International Colloquium on , vol.1, no., pp.528-532, 3-4 Aug. 2008

Tick Hui Oh, Shing Chyi Chua, Energy efficiency and carbon trading potential in Malaysia, Renewable and Sustainable Energy Reviews, Volume 14, Issue 7, September 2010

Yachuan Yao; Yi Yao; Hong Song, "The Remote Monitoring System Based on the OPC Technology," in Intelligent Systems and Applications, 2009. ISA 2009. International Workshop on , vol., no., pp.1-3, 23-24 May 2009

Ye Dun-fan;Min Liang-liang; Wei Wang, "Design and Implementation of Wireless Sensor Network Gateway Based on Environmental Monitoring," in Environmental Science and Information Application Technology, 2009. ESIAT 2009. International Conference on , vol.2, no., pp.289-292, 4-5 July 2009

Zhisong Wang; Shihua Li; Qi Hao; Linlin Li; Guotao Zhai, "Research of intelligent greenhouse remote monitor system based on embedded network and wireless transmission technology," in Electrical and Control Engineering (ICECE), 2011 International Conference on , vol., no., pp.1688-1691, 16-18 Sept. 2011

C.E Dickerson,D.N Mavris. (2009). *Architecture and Principles of Systems Engineering*. United States of America: CRC Press.

A Kossiakoff, William N. Sweet. (2003). *Systems Engineering Principles and Practice*. United States of America: Wiley.

Benjamin S. Blanchard. (2008). *Systems Engineering Management*.Fourth Edition. United States of America: Wiley.

Hans-Joachim Leimkühler, (2010) " Managing CO2 Emissions in Chemical Industry" , 1st Edition, United States of America Wiley,

Asia Pacific Network for Global Change Research (2015, December 1). Low Carbon Initiative Network. Retrieved from the Agency Website: http://www.apn-gcr.org/programmes-and-activities/focused-activities/low-carbon-initiatives-framewok/

Intergovernmental Panel on Climate Change (2015, December 5). IPCC Fourth Assessment Report: Climate Change 2007. Retrieved from the Agency Website: http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html

Open Energy Monitor Organization (2016, January 16) Open Energy Monitor Project Retrieved from the Organization Website: https://openenergymonitor.org/