IMPACT OF CURRENT REFRIGERANT REPLACEMENT USED IN UNIVERSITI TEKNOLOGI MALAYSIA

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DEDICATION

"To my beloved mother, Norliza Abd. Ghani and father, Alias Mohd Yusof, my siblings Fara Nabila Alias, Ahmad Affifuddin Alias, Ahmad Azeem Alias, Fisya Iezzati Alias, Fathi Firjani Alias and Danniel Adha Abd Rahman for their everlasting love, support, pray and concern."

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ABSTRACT

Many institutions of higher education have begun to integrate sustainable development into their system. Universiti Teknologi Malaysia (UTM) was chosen as a case study to access the impact of replacing hydrochlorofluorocarbon (HCFC) with hydrofluorocarbon (HFC) in its air-conditioning systems. UTM has installed new air-conditioning units using R-410A (HFC) and replaced current systems that use R-22 (HCFC). UTM also have used a chiller unit using R-134A (HFC) replacing with old refrigerant which is R-123 (HCFC). Currently UTM, does not possess a proper guideline with sufficient inventory database to assist the management team in making any decision on replacing the current HCFC with HFC or any other refrigerant that is more environmentally friendly. The objective of this research is to (1) Estimate the Total Equivalent Warming Impact (TEWI) and leakage rate in air-conditioning unit that currently use R-22 (HCFC) and R-410A (HFC) as refrigerants; (2) Differentiate in terms of TEWI for R-32 (HFC), R-161 (HFC) and R-290 (HC) as alternative to substitute current refrigerant and (3) Determine potential reclamation of used refrigerant R-123 (HCFC) that can be recovered back to the system as it is possible to avoid direct release to the atmosphere. TEWI takes into account both direct and indirect emissions in four maintenance zoning areas. The leakage rate was determined by retrospective approach method. Currently, in all four maintenance zone there are 4,261 units which is 64.1% of split air-conditioning using HCFC. Highest TEWI value was detected in Zone 1 which is 130,057.14 t eq CO_2/year while Zone 4 has the highest leakage rate among the four zones which is 473.79%. To support decision making, this study differentiate TEWI of HFC and HC as alternative substitute refrigerants. The result shows that carbon emission for R-32 (HFC) is 254,225.9 t eq CO_2/year, R-161 (HFC) is 250,896.0 t eq CO_2/year and R-290 (HC) is 250,884.9 t eq CO_2/year. In order to manage the used refrigerant, this study also focused on refrigerants with recovery potential which is Chiller at Block C12 which is one of the targeted unit to dispose for replacement of HCFC. A sample of HCFC was recovered from the chiller unit to undergo the reclamation process. From the impurity test all samples passed the AHRI-700 standards. Hence, the results indicated that the sample can undergo reclaim process. A total of 79.21% of HCFC was recovered at the end of the recovery process and can be reused in the same system. From this study, it would help Universiti Teknologi Malaysia Office Asset and Development (UTM OAD) to develop a plan to decide use of environmentally friendly refrigerant with no Ozone Depletion Potential (ODP) and low Global Warming Potential (GWP) in new and existing air-conditioning unit systems. In conclusion, the method of data collection can influence HCFC's phase-out as required by national regulation. This data would act as a guideline to ensure a successful phase-out is being carry out and assist in determine the best refrigerants to be replace in the future in the conditions of higher education institutions towards sustainability.

ABSTRAK

Kini institusi pendidikan tinggi telah mula mengintegrasikan pembangunan lestari ke dalam sistem mereka. Universiti Teknologi Malaysia (UTM) dipilih sebagai kajian kes untuk mengakses impak menggantikan hidrokloroflorokarbon (HCFC) dengan hidroflorokarbon (HFC) dalam sistem penghawa dinginnya. UTM telah memasang unit penghawa dingin baru menggunakan penyejuk R-410A (HFC) dan menggantikan sistem sedia ada yang masih menggunakan R-22 (HCFC). UTM juga telah menggunakan unit penyejuk yang menggunakan R-134A (HFC) bagi menggantikan R-123 (HCFC). Pada masa ini, UTM tidak memiliki garis panduan serta pangkalan data inventori yang mencukupi untuk membantu pasukan pengurusan dalam membuat keputusan mengenai penggantian HCFC kepada HFC atau mana-mana penyejuk lain yang lebih mesra alam sekitar. Objektif kajian ini adalah untuk (1) Menganggarkan Jumlah Kesan Pemanasan Bersamaan (TEWI) dan kadar kebocoran dalam unit penghawa dingin yang kini menggunakan R-22 (HCFC) dan R-410A (HFC) sebagai penyejuk; (2) Membezakan dari segi TEWI untuk R-32 (HFC), R-161 (HFC) dan R-290 (HC) sebagai alternatif pengganti penyejuk semasa dan (3) Menentukan potensi proses pemulih gunaan yang dijalankan pada R-123 (HCFC) mengelakkan pembebasan langsung ke atmosfera. TEWI mengambil kira kedua-dua pelepasan secara langsung dan tidak langsung dalam empat kawasan zon penyelenggaraan. Kadar kebocoran ditentukan oleh pendekatan retrospektif. Kini, dalam semua empat zon penyelenggaraan terdapat 4,261 unit iaitu 64.1% penghawa dingin unit pisah menggunakan HCFC. Nilai TEWI tertinggi dikesan di Zon 1 iaitu 130,057.14 tan CO_2/tahun sementara Zon 4 mempunyai kadar kebocoran tertinggi di antara empat zon iaitu 473.79%. Di samping itu, kajian ini membezakan TEWI daripada HFC dan HC sebagai alternatif penyejuk yang digunakan. Hasilnya menunjukkan pelepasan karbon untuk R-32 (HFC) ialah 254,225.9 tan CO_2/tahun, R-161 (HFC) adalah 250,896.0 tan CO_2/tahun dan R-290 (HC) adalah 250,884.9 tan CO_2/tahun. Dalam usaha untuk menguruskan penyejuk yang digunakan, kajian ini juga memberi tumpuan kepada penyejuk unit di Blok C12 yang mempunyai potensi pemulihan, dimana ia merupakan salah satu unit yang disasarkan untuk dilupuskan bagi menggantikan HCFC. Sampel HCFC telah menjalani proses pemulih gunaan. Dari ujian bendasing, semua sampel melepasi piawaan AHRI-700. Oleh itu, keputusan menunjukkan bahawa sampel boleh menjalani proses pemulih gunaan. Sebanyak 79.21% HCFC boleh digunakan semula dalam sistem yang sama. Dari kajian penyelidikan ini, ia akan membantu pihak Pejabat Harta Bina Universiti Teknologi Malaysia (UTM OAD) untuk merancang untuk memutuskan penyejuk baru yang mesra alam tanpa Potensi Pengrusakan Ozon (ODP) dan Potensi Pemanasan Global (GWP) yang rendah dalam sistem unit penghawa dingin sedia ada. Sebagai kesimpulan, kaedah pengumpulan data ini boleh mempengaruhi pemansuhan HCFC seperti yang dirangka dalam undang-undang peringkat kebangsaan. Data ini akan bertindak sebagai garis panduan dan membantu menentukan penyejuk terbaik untuk digunakan pada masa hadapan agar selari dengan agenda institusi pengajian tinggi ke arah kelestarian.

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LIST OF ABBREVIATIONS

AHRI	-	Air-conditioning, Heating & Refrigeration Institute
AIRAH	-	Australian Institute of Refrigeration, Air conditioning and Heating
AP	-	Approved Permit
ASHRAE	-	American Society of Heating, Refrigerating and Air-Conditioning Engineers
Br	-	Bromine
CFC	-	Chlorofluorocarbon
Cl	-	Chlorine
CO_2	-	Carbon dioxide
CO_{2-e}	-	Carbon dioxide equivalent
DIW	-	Department of Industrial Work
DOE	-	Department of Environment
EPA	-	Environmental Protection Agency
F	-	Fluorine
FC	-	Fluorocarbon
GHG	-	Green House Gases
GWP	-	Global Warming Potential
H	-	Hydrogen
HC	-	Hydrocarbon
HCFC	-	Hydrochlorofluorocarbon
HFC	-	Hydrofluorocarbon
HP	-	Heat Pump
HPMP	-	Hydrofluorocarbons Phase-out Management Plan
HVAC	-	Heating, ventilation, and air conditioning
I	-	Iodine
IEC	-	International Electrotechnical Commission
IHX	-	Internal Heat Exchanger
IPCC	-	The Intergovernmental Panel on Climate Change
ISO	-	International Organization for Standardization

METI	-	Ministry of Economy, Trade and Industry
MITI	-	Ministry of International Trade and Industry
MLF	-	The Multilateral Fund
ODP	-	Ozone Depletion Potential
ODS	-	Ozone Depleting Substances
OPU	-	Ozone Protection Unit
RAC	-	Refrigeration and Air-conditioning
TEWI	-	Total equivalent warming impact
UNDP	-	United Nations Development Programme
UNEP	-	United Nations Environment Programme
UNFCCC	-	United Nations Framework Convention on Climate Change
UNIDO	-	United Nations Industrial Development Organization
US EPA	-	United State Environmental Protection Agency
UTM	-	Universiti Teknologi Malaysia
UTM OAD	-	Universiti Teknologi Malaysia Office Asset and Development
UV	-	Ultraviolet
WMC	-	Waste Management Centre

LIST OF SYMBOLS

$\alpha_{recovery}$	-	Recovery/recycling factor from 0 to 1
β	-	Indirect emission factor
E_{annual}	-	Energy consumption per year
L_{annual}	-	Leakage rate per year
m	-	Refrigerant charge
n	-	System operating life

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

In Malaysia, widely used refrigerants in air-conditioning systems include hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). In order to protect the ozone layer the phase-out of chlorofluorocarbons (CFCs) as mandated by the Montreal Protocol leading to consequent reduction of emissions and atmospheric concentrations of contributed that led to climate change (Polonara *et al.*, 2017). This is due to CFCs has a potential to deplete ozone layer and cause the greenhouse effect more significant than HCFCs and HFCs. However, the HCFCs are still contributing to the ozone depletion process as it contains chlorine. Malaysia had agreed to ban the usage and manufacturing of CFCs and HCFCs (Razman and Hadi, 2010). These HCFC and HFC refrigerants have been recognised as substitutes to CFCs refrigerant that has been banned since 1996 (Aprea *et al*., 2004). Besides impacting the environment through Ozone Depleting Potential (ODP), HCFCs and HFCs contain carbon and when released to the atmosphere they will impose negative impact to the environment directly or indirectly.

Direct carbon emission indicate that the refrigerant is being released into the atmosphere intentionally or unintentionally. Improper handling during maintenance or extraction of refrigerant has resulted to unintentional release (Francis *et al*., 2017). There have been cases where contractors or service providers knowingly release the refrigerants after extraction from the air-conditioning system. This is due to lack of knowledge and awareness for reclamation or destruction practises in Malaysia.

Indirect carbon emission from the energy use in air-conditioning production and operation. Every refrigeration system would require electricity to operate and electricity is being generated either using coal power plant or hydroplants. However, in Malaysia, coal power plant is the most common source of energy hence the higher capacity used by a single refrigeration system, it indirectly contributes to the indirect carbon release.

Different refrigeration system requires different energy consumption and higher energy consumption contributes to a higher indirect carbon emission. HCFCs are used as interim replacement for CFCs but will be phased out by the year 2030. HCFCs will be replaced with hydrofluorocarbons (HFCs) or Hydrocarbon (HCs) depending on both refrigerants potential in contributing towards the ozone depletion (Tsai, 2013).

1.2 Problem Statement

Based on Malaysia HCFCs Phase-out Management Plan (HPMP) Stage-1, Malaysia has consumed 6,255 Metric Tonnes of R-22 (HCFC) in 2009 with an overall HCFCs average annual growth rate of over 18% (DOE, 2012). The continuous increase in HCFCs consumption was defined as a continuous economic development resulted by the increase in market demand, commercial and industrial products that requiring HCFCs use or operating on HCFCs, particularly in the refrigeration and air-conditioning sectors. HPMP Stage-2 has been approved by the Executive Committee in Malaysia to phase-out 146.24 ODP ton HCFCs where the implementation period started from 2017-2022 (DOE, 2018). By 2017, an estimated 18% of HCFCs will be phased out after completion of the Stage-1 of HPMP. For the preparatory activities in achieving 65% of the target to be achieved by 2025. Next, achieve 35% phase-out target in 2020 government requested Montreal Protocol Multilateral Fund for the preparation of HPMP Stage-2 in 2015 (DOE, 2018).

R-22 (HCFC) is a powerful greenhouse gas with a Global Warming Potential (GWP) equal to 1,810 which indicates 1,810 times as powerful as carbon dioxide while R-410A (HFC) GWP is equal to 2090 (Koh *et al.*, 2017). R-22 (HCFC) is classified as ozone depleting substances (ODS) as it contains chlorine as part of its chemical bonding (EPA, 2015). ODS of a chemical compound is the relative amount of degradation to the ozone layer it can cause. In this case R-22 (HCFC) contain ODP of 0.05 and whereby R-410A (HFC) has no ODP (Han *et al.*, 2012).

Many institutions of higher education have begun to integrate sustainable development into their system. Universiti Teknologi Malaysia (UTM) was chosen as a case study for this research due to its intention in proceeding with the phase-out plan and abiding to the national regulation. As part of its initiative, UTM has installed new air-conditioning units using R-410A (HFC) and replaced current systems that use R-22 (HCFC). In order to further elaborate the efforts, UTM has chosen as part of an initial phase-out effort. As initial effort, UTM have involve a chiller unit used R-134A (HFC) as its refrigerant replacing R-123 (HCFC). The chiller unit should undergo a complete system change, enabling the new system to function using R-134A (HFC).

The process of replacing refrigerants to abide to the current regulation. Without proper data collection, the data collection would not be complete and would not reflect the whole situation in UTM. UTM, currently does not have any proper guideline as well as sufficient inventory database to assist the management team in making any decision on replacing the current R-22 (HCFC) or R-410A (HFC) with any other refrigerant that is more environmental friendly. The collection of data on the leakage rate is also vital as direct release could be monitored (Ohm *et al*., 2015). As refrigerant possesses different GWP, this data would assist the management to target zoning areas which release a larger amount of refrigerant causing a bigger impact on the environment. Updating this study's current results to UTM, it would help UTM completely understand their ability to contribute to sustainable development.

The selection of refrigerant is based on HPMP and Montreal Protocol whereby there are few potential refrigerant replacements available namely R-32 (HFC), R-161 (HFC) and R-290 (HC). Unlike R410-A (HCFC), all these refrigerants do not pose any harm toward the ozone layer. However, R-32 (HFC), R-161 (HFC) and R290 (HC) are flammable, hence posing risks as split unit air-conditionings are commonly used in residential houses *(Wu et al*., 2012 , Mohanraj *et al*., 2009). In addition, HFCs with high GWP are climate concerns and the reasons behind the Kigali Amendment of the Montreal Protocol adopted during the 28th Meeting of the Parties 8-14th October 2016 in Kigali, Rwanda (Purohit *et al.*, 2018). Malaysia, under developing countries (A5) will freeze HFC consumption by 1st January 2024. Gradually reducing the dependency, starting with the reduction of 10%, 30%, 50%, 80% for the year, 2029, 2035, 2040 and 2045, respectively (Polonara *et al.*, 2017). The Kigali Amendment will enter into force on 1st January 2019, provided that it has been ratified by at least 20 Parties to the Montreal Protocol.

1.3 Objectives of the Study

Three objectives have been set out in this research consisting of:

(a) To estimate Total Equivalent Warming Impact (TEWI) R-22 (HCFC) and R-410A (HFC) currently used in existing equipment and leakage rate in air-conditioning units system in UTM.

(b) To differentiate in terms of TEWI of R-32 (HFC), R-161 (HFC) and R-290 (HC) as alternative substitutes for current refrigerants used.

(c) To determine potential reclamation of used refrigerant R-123 (HCFC) to be used back in efforts to avoid negative impact into environment

1.4 Scope of the Study

The scope of the study is to estimate the potential of the direct and indirect release of carbon emission in 2016 at four zoning areas as designated by Universiti Teknologi Malaysia Office of Asset and Development (UTM OAD). This includes calculating estimation on refrigerant leakage rates in split unit air-conditioning systems. This study only focused on the environmental impact based on only an ODP and GWP. It also focused on refrigerants in selected chiller units involved in the reclamation process. The year 2016 was appropriated as 2015 marked the beginning of Malaysia’s HCFC phase-out plan and the change to HFCs.

1.5 Significance of the Study

In support of and fulfilling Malaysia’s obligations under the Montreal Protocol, the government has implemented its efforts through designing and executing many policies in order to gradually ban the CFCs. The first plan that has been executed was the ‘National FC Country Program’ that tackle from 1992 to 2001. This program is then succeeded with ‘National ‘CFC Phase-out Plan’ from 2002 till 2010. Since 2011 till 2016, the Government has launched ‘National HCFC Phase-out Plan’ to remove HCFCs from the market.

Then, Montreal Protocol calls for the phasing out of HCFC gases used as refrigerants and the need for substitutes that exhibit lower ozone depleting risks. Therefore, the enforcement of the Montreal Protocol has provided an impetus for the development and investment on a new generation of energy efficient air-conditioning systems and ozone-friendly refrigeration equipment. In the wake of the phase-out of HCFC, demand for hydrofluorocarbons (HFCs) grew and traces of HFC in the atmosphere began rapidly increasing. Although HFCs only comprise a small percentage of the total greenhouse gases (GHG) in the atmosphere, they have the capacity to trap more than 1,000 times the heat trapped by carbon dioxide. If not properly managed, HFC emissions have the potential to increase global temperatures by 0.5 degrees Celsius by 2100. In Kigali amendment, Malaysia is listed among significant HFC consumer which is to phase down baseline HFC and HCFC component and reaching freeze on 2024.

Universiti Teknologi Malaysia (UTM) Campus Sustainability in the Low Carbon City Framework (LCCF) and evaluation scheme provides numerous opportunities to explore and accelerate the strategic low carbon initiative. The research is aligned with the current UTM My Carbon is a measurement of greenhouse gas in UTM. Measuring carbon produced from activities involving carbon release from several water, waste, air, transportation and energy sectors. UTM My Carbon evaluates direct emissions and indirect emissions. It will investigate the current status of HCFCs use in UTM. This action will act as a support to the government's efforts to gradually phase-out HCFCs and will provide the necessary relevance information towards this policy and future efforts. The main constraints for transitioning from HCFCs to alternatives that are environment-friendly substitutes. This research would determine the alternative substitute as environment-friendly based on its direct and indirect carbon release.

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