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A STUDY ON GREENHOUSE GAS REDUCTION PLAN IN A MALAYSIAN HOME

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ABSTRACT

This Greenhouse Gas (GHG) Reduction Plan study is based on a residence solely powered by direct electricity from the national power grid. Most of the energy is utilized for cooling the ambient temperature through air-conditioning and refrigeration for food preservation and by doing so help to reduce energy cost with the added advantage of a healthier environment. This project is a demonstration of the homeowner's concern about environmental degradation which will affect the household and particularly the children living within. The methodology is adopted from The Climate Registry (TCR) and the inventory boundary includes the perimeter of the home covering mandatory gases of CO2, N2O and CH4. To mitigate GHG strategies, opportunities were identified using scope 2 purchase electricity and direct GHG emission source for mobile combustion of fuels. The household energy usage contributing the highest quantity of CO2 was listed for prioritization. The mitigation strategies are entirely internally funded as they do not attract any grant or incentives from local authorities. Data are electronically managed for quarterly review and yearly audit to ascertain if the estimates/calculations have data gaps. As part of the strategies to implement Knowledge Management (KM), data will be IT centric to facilitate capture, access, and reuse of information to analyze, track and to report for future improvements.

1.0 Introduction

The house under study has a reinforced concrete structural frame. The brick wall is made from sand/cement. The roof consists of concrete tiles with timber trusses. The house was built seven years ago but can be considered fairly new in comparison to others in the vicinity. The house electrical system is solely powered by directly from the national grid. Radiant heat build-up is a problem and most energy is dedicated to cooling the ambient temperature by the use of split unit air-conditioning systems for the bedrooms and fans for other areas. External daytime temperature averages 33 °C but heat retention in the house, particularly on the upper floors where the bedrooms are located, is about 30°C at night. The Malaysian single season warm weather does not warrant a need for gas-piped heaters for hot water to shower or wash clothes. Instant water heaters are installed for short-spell usage Refrigerators for food preservation are on for 24 hours everyday while air conditioners are intermittently used for environmental cooling.

2.0 The Need for GHG Reduction

Since the dawn of the Industrial Revolution, the concentration of GHG, mainly CO2, has increased by 30% principally due to the burning of fossil fuels, changes in land use and fertilizers. There is an urgent need to undertake local action that will contribute to global emission reduction. By doing so it is possible to derive individual benefits such as reduced energy cost and a healthier environment for personal lifestyles.

3.0 Goals

This project is a demonstration of the homeowner's concern about environmental degradation affecting future generations. The project's goal is simply to reduce GHG emissions at home and to address issues relating to commuting using the family car.

The choice of using 2009 as a baseline is due to the availability of fuel receipts/data. In terms of GHG reduction by absolute targets, the goal is to reduce by up to 20% of CO2e by 2012 over the 2009 baseline.

4.0 GHG Inventory

At the community level, there is no standard protocol for GHG inventories (Bolduc 2010). For this project, the methodology will be adopted from the General Reporting Protocol (GRP) for Voluntary Reporting Program published by The Climate Registry (2008). The boundary of this inventory includes the geographic perimeter of the home area and the family car used for commuting. The data collection includes the mandatory gases of CO2e such as N2O and CH4 which are described below.

4.1 Home Boundary GHG Inventory

The boundary is defined as the geographic perimeter enclosing the property owned. The indirect emission source to be reported is based on the boundary for the base year of 2009. The emission factor is based on metered readings/utility bills cited as TCR tier B and chosen because the energy supply routing had multi-loop/grid connections that causd uncertainty in the measurement of actual heat content of the fuels combusted. It is common for a Malaysian energy provider not to provide for emission factors and the geographic locations of the utility grids are not fully published for security reasons as these essential services (including Independent Power Producers) are in full control of the Government. As the home unit is powered by purchased electricity, it is classified as Scope 2 reporting. Using GRP's guideline, the emission quantifications based on appropriate Malaysian eGRID conversion factors is listed in Figure 1. Sources of emission rates are based on natural gas at 0.53kg of CO2/kwh/unit and 0.0009 N2Okg/kwh of electricity (Saidur *et. al.*. (2009); Masjuki *et. al.* (2002). The sum of Metric Ton of Carbon Dioxide Equivalent (MTCDE) for the home unit is 4.162336 as listed in Figure 1a.

Figure 1: Home Utility Bills from February 2009 to January 2010

*Bill from date	*Bill to date	Days in Bill	Temp °C Min. Ave. Max.	Total usage kwh	CO2/kwh (kg)**	Monthly CO2/kwh (kg)
20-02-2009	23-03-2009	33	23.1 - 28.3 - 32.5	449	0.53	237.97
24-03-2009	21-04-2009	29	23.4 - 28.35 - 33.3	481	0.53	254.93
22-04-2009	22-05-2009	31	23.8 - 30.9 - 33.5	543	0.53	287.79
23-05-2009	21-06-2009	30	24.2 - 28.85 - 33.5	425	0.53	225.25
22-06-2009	22-07-2009	31	24.3 - 28.8 - 33.3	473	0.53	250.69
23-07-2009	22-08-2009	31	24.1 - 28.6 - 33.1	484	0.53	256.52
23-08-2009	19-09-2009	28	23.7 - 27.8 - 32.6	314	0.53	166.42
20-09-2009	21-10-2009	32	23.7 - 28.2 - 32.7	420	0.53	222.60

22-10-2009	19-11-2009	29	23.6 - 28.05 - 32.5	412	0.53	218.36
20-11-2009	22-12-2009	33	23.7 - 28.1 - 32.5	359	0.53	190.27
23-12-2009	21-01-2010	30	23.6 - 27.85 - 32.1	324	0.53	171.72
22-01-2010	18-02-2010	28	23.3 - 27.6 - 31.9	332	0.53	175.96
*Electricity utility bills		365	*Met. Dept.	5016		**2658.48 kg**

Figure 1a: Home Quantification of CO2e

Emission quantifications	kg CDE	MTCDE
CO2 emissions =5016kwh x 0.53 CO2/kwh	2658 kg	2.658
N2O emissions = 5016kwh x 0.0009 N2O kg/kwh=4.5144kgsx310GWP	1399.464	1.399
CH4 = 5016kwh x 0.001kg/mmbtu = 5.016kgx 21GWP	105.336	0.105336
Sum of MTCDE	4162.80	4.162336

4.2 Vehicle in GHG Inventory

The direct GHG emissions are from the combustion of fuels by the family car used for daily commuting to work, school and recreation. Emission factors use TCR data quality tier B because there is no data on distance travelled except for fuel usage extracted from the collected fuel receipts and monthly fuel purchases statement. Quantifications are made using GHG protocol mobile guide v1.3 (2005) and World Business Council for Sustainable Development (WBCSD), World Resources Institute (WRI) (2004) with sum of 18.0255 MTCDE as described in Figure 2.

Figure 2: Vehicle GHG Inventory

Mobile combustion for vehicle CO2	kg CDE	MTCDE
Estimating fuel use based on distance Distance/(city fuel economy x city % + highway FE x highway%) Emission factor-Vehicle type -medium gas auto 10.7 liters/100 km (254.7gm CO2/km) 1 liter = 1/10.7 x100 = 9.35 km - Fuel use 7440 liters x 9.35 = 69564 km - 1 gallon = 3.7854 liters - 1 mile= 1.60934 km - FE 25 mpg = 40.2335 km/3.7854 = 10.63 km/liter 69564 km x 254.7g CO2/km = 17,717,950 g	17,717.95	17.717
ii N20 emission: 0.0079 gm/mile (1 mile = 1.60934 km) 0.0079 g/mile x 1.60934 = 0.012714 x distance 69564 km = 884.415 gm/1000 = 0.8844 kg x310 GWP = 274.1689 kg CO2e	274.1689	0.274
iii CH4 emission gm/mile (mile = 1.60934 km) 0.0147 g/mile x 1.60934=0.0236573 x distance 69564 km =1645.69 gm/1000=1.64568 kg x21 GWP=34.56 kg CO2e	34.56	0.03456
Sum of MTCDE	18,026.67	18.0255

5.0 Third Party Audits

Verification is an objective assessment of the accuracy and completeness of reported GHG information and the conformity of this information to pre-established GHG accounting and reporting principles (WBCSD WRI 2004). Since this is a private home adopting a voluntary reporting program, there will not be any independent evaluation of the accuracy of emission reports and their conformity with the GRP's requirements. Moreover, the location of this home is in Malaysia therefore does not fall under the typical jurisdiction

TCR. Nevertheless, the verification to ensure accuracy and completeness of the data obtained in this project shall be conducted by the homeowner through annual audit to determine if the goal of the project is met i.e. GHG Reduction Plan.

6.0 Mitigation Strategies

Some of the proposed mitigation projects include purchase of inverter based (20%) energy saveing refrigeration, air-conditioner, washing machine and electronic controlled water heater as listed in Figures 3b, 3c, 3d, 3e and 3f.

Figure 3b: New Inverter System Refrigerator with 20% GHG Reduction

Refrigerator	Total Cost	$7,000			
	Rebate	0			
	Net Cost	**$7,000**	Annual Savings (FY10 rates)	20% Emissions Reductions (MTCDE)	
				Annual	10 yrs
Annual Savings	Maintenance ($)	100	$100		
Electric Direct Service	Residential (kWh)	2,628	$494	1.8	18
		Annual Savings	**$594**		

Life Expectancy	
Expected life of equipment (years)	10
Replacement cost in **FY10** Dollars	$7,000
Simple Payback Analysis	
Annual Savings (FY10 rates)	$594
Simple Payback Period	0.72
10 Year Net Present Value	($3,416)
Savings to Investment Ratio	0.72
10 Yr Investment Cost / 10 Yr MTCDE	$139.56
NPV / Total GHG Reduction	($19.41)
Discounted Payback Period	See 'Net Savings' graph
Internal Rate of Return	1.80%

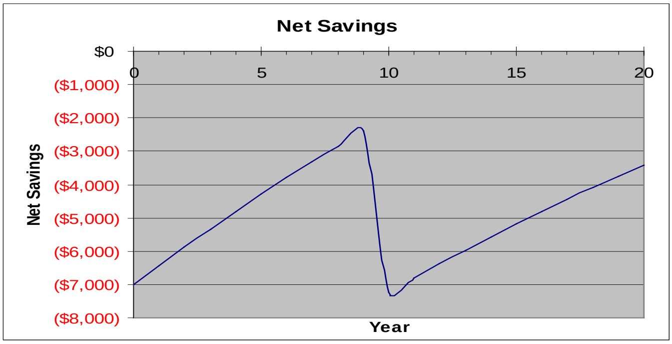


Figure 3c: New Inverter System Air-conditioning with 20% GHG Reduction and Savings

Air-conditioning	Total Cost	$4,500			
	Rebate	0			
	Net Cost	**$4,500**	Annual Savings (FY10 rates)	20% Emissions Reductions (MTCDE)	
				Annual	10 yrs
Annual Savings	Maintenance ($)	300	$300		
Electric Direct Service	Residential (kWh)	1,440	$271	0.8	8.2
		Annual Savings	**$571**		

Life Expectancy	
Expected life of equipment (years)	10
Replacement cost in **FY10** Dollars	$4,500
Simple Payback Analysis	
Annual Savings (FY10 rates)	$571
Simple Payback Period	7.88
10 Year Net Present Value	$659
Savings to Investment Ratio	1.08
10 Yr Investment Cost/10 Yr MTCDE	$186.20
NPV / Total GHG Reduction	$7.77
Discounted Payback Period	See 'Net Savings' graph
Internal Rate of Return	9.68%

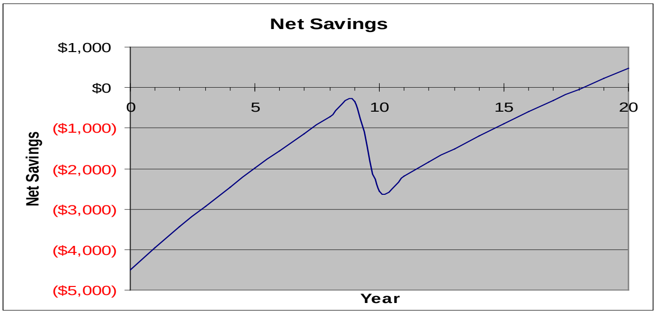


Figure 3d: New Washing Machine with Inverter System for 20% GHG Reduction and Savings

Washing machine	Total Cost	$3,000			
	Rebate	0			
	Net Cost	**$3,000**	Annual Savings (FY10 rates)	20% Emissions Reductions (MTCDE)	
				Annual	10 yrs
Annual Savings	Maintenance ($)	250	$250		
Electric Direct Service	Residential (kWh)	1,188	$223	0.8	8
		Annual Savings	**$473**		

Life Expectancy	
Expected life of equipment (years)	10
Replacement cost in **FY10** (Dollars)	$3,000
Simple Payback Analysis	
Annual Savings (FY10 rates)	$473
Simple Payback Period	6.34
10 Year Net Present Value	$1,832
Savings to Investment Ratio	1.35
10 Yr Investment Cost/10 Yr MTCDE	$150.38
NPV / Total GHG Reduction	$26.17
Discounted Payback Period	See 'Net Savings' graph
Internal Rate of Return	14.61%

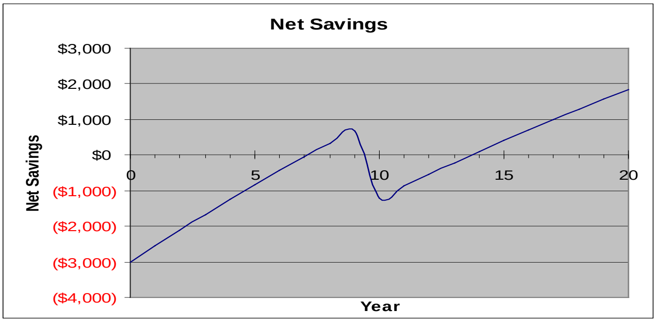


Figure 3e: New Electronically Controlled Water Heater with 20% GHG Reduction and Savings

Water heater	Total Cost	$2,000			
	Rebate	0			
	Net Cost	**$2,000**	Annual Savings (FY10 rates)	Emissions Reductions (MTCDE)	
				Annual	10 yrs
Annual Savings	Maintenance ($)	200	$200		
Electric Direct Service	Residential (kWh)	972	$183	0.6	6
		Annual Savings	**$383**		

Life Expectancy	
Expected life of equipment (years)	10
Replacement cost in **FY10** Dollars	$2.000

Simple Payback Analysis	
Annual Savings (FY10 rates)	$383
Simple Payback Period	5.23
10 Year Net Present Value	$2,228
Savings to Investment Ratio	1.63
10 Yr Investment Cost/10 Yr MTCDE	$122.70
NPV / Total GHG Reduction	$38.94
Discounted Payback Period	See 'Net Savings' graph
Internal Rate of Return	19.50%

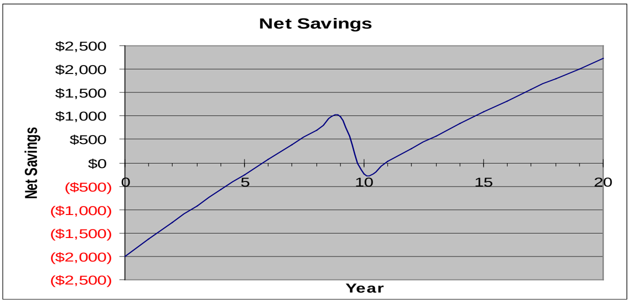
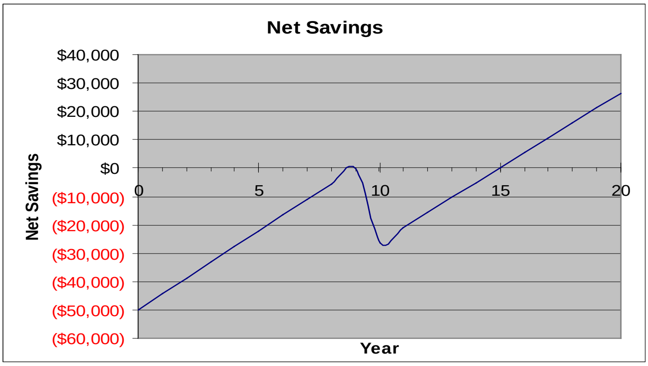


Figure 3f: New Low Fuel Efficiency Family Car with 30% GHG Reduction and Savings

Assumptions	Discount Rate	10.00%			
	Utility Escalation Rate	10.00%			
	Maintenance Escalation Rate	5.00%			
	Escalation rate for one-time costs	5.00%			
	Study Period (years)	10			
	Cost of Carbon	$0			
Family car	Total Cost	$50,000			
	Rebate	0			
	Net Cost	**$50,000**	Annual Savings (FY10 rates)	30% Emissions Reductions (MTCDE)	
				Annual	10 yrs
Annual Savings	Maintenance ($)	800	$800		
Fuel oil	Annual use in gallons	1966	$5,112	5.4	54
		Annual Savings	**$5,912**		

Life Expectancy	
Expected life of equipment (years)	10
Replacement cost in **FY10** Dollars	$50,000

Simple Payback Analysis	
Annual Savings (FY10 rates)	$5,912
Simple Payback Period	8.46
10 Year Net Present Value	$26, 359
Savings to Investment Ratio	1.32
10 Yr Investment Cost /10 Yr MTCDE	$452.22
NPV / Total GHG Reduction	$73.22
Discounted Payback Period	See 'Net Savings' graph
Internal Rate of Return	15.03%



The following opportunities were broken down in order to identify GHG mitigation strategies as below:

a) The home is powered by scope 2 purchase electricity which is natural gas generated at 0.53kg of CO2/kwh/unit and 0.0009 N2Okg/kwh (Saidur *et. al.*. 2009; Masjuki *et. al.*. 2002). The sum of MTCDE is 4.162336 as listed in Figure 2a.

Figure 2a: Purchased Electricity Emissions

Purchased electricity emissions	**Kg CDE**	**MTCDE**
CO2 emissions =5016kwh x 0.53 CO2/kwh	2658kg	2.658
N2O emissions = 5016kwh x 0.0009 N2O kg/kwh=4.514kgsx310GWP	1399.464	1.399
CH4 = 5016kwh x 0.001kg/mmbtu = 5.016kgx 21GWP	105.336	0.105336
Sum of MTCDE	4162.80	4.162336

b) Direct GHG emission source is from the mobile combustion of fuels by the family car and quantifications are made using GHG protocol scope 1 mobile guide v1.3 (2005) and WBCSD WRI (2004) and the sum of MTCDE at 18.0255 found in Figure 2b.

Figure 2b: Mobile Combustion for Vehicle

Mobile combustion for vehicle CO2 based on 7440L/3.7854=1966 gallon	**Kg CDE**	**MTCDE**
i Estimation based on distance of 69564km x 254.7g CO2/km	17,717.95	17.717
ii N20 emission g/mile x km x distance x 310GWP	274.1689	0.274
iii CH4 emission g/mile x km x distance x 21GWP	34.56	0.03456
Sum of MTCDE	18,026.67	18.0255

By ranking GHG emissions, the mobile emission (vehicle) took the lead at 81.24 MTCDE followed by purchased electricity at 18.75 MTCDE as described in Figure 2c. In terms of home energy usage by floor area, the refrigerator had the highest MTCDE at 8.8, followed by the air-conditioner at 4.24, the washing machine at 3.5 and the water heater at 2.86. All the appliances ranking by GHG emissions are listed in Figure 2d. From the breakdown of household energy usage (Figure 3), the equipments that contributed the highest quantity of CO2 were listed for prioritization of GHG reduction plans in descending order of refrigerator, air conditioner, washing machine, water heater and family car. The Harvard LCC tool with a discount rate of 8-10% was used for estimating purchase of new home appliances and compact fuel efficiency family car as listed in Figure 3a.

Figure 2c: Ranking of GHG Emissions by Types

Types of emission	MTCDE	% of MTCDE
Mobile emissions (car)	18.02	81.24
Purchased electricity (home)	4.16	18.75
Total emissions	22.18	100

Figure 2d: Breakdown of Estimated Home Energy Usage based on Area of 180 m2

Item	kw	hours/year	kwh	kwh/m2/year	%	Co2	MTCDE
Refrigerator	0.3	8760	2628	16.6	38	0.53	8.798
Air conditioner	1	1440	1440	8	21	0.53	4.24
Washing machine	2.2	540	1188	6.6	17	0.53	3.498
Water heater	2.7	360	972	5.4	14	0.53	2.862
Rice cooker	0.65	360	234	1.3	3	0.53	0.689
Iron	1	180	180	1	3	0.53	0.53
Fan	0.045	3600	162	0.9	2	0.53	0.477
TV	0.06	1080	64.8	0.36	1	0.53	0.191
Radio	0.25	72	18	0.1	0	0.53	0.053
Florescent lamps 18w	0.032	288	9.126	0.0512	0	0.53	0.02714
Florescent lamps 18w	0.192	288	55.296	0.3072	1	0.53	0.1628
Vacuum cleaner	0.3	96	28.8	0.16	0	0.53	0.0848
TOTAL	8.729	17064	6980.11	38.7784			21.613

Source: Adapted from Chan (2004)

Figure 3: Breakdown of Household Energy Usage by Percentage

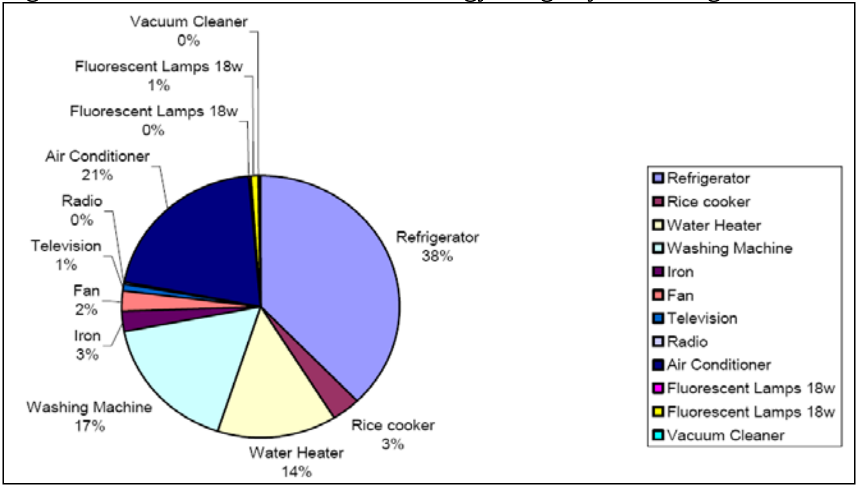


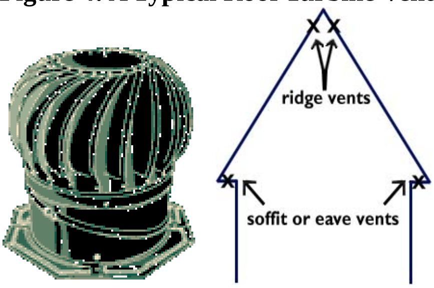
Figure 3a: Estimating New Home Appliances and Family Car

Project Information	Home GHG mitigation	PJ Home	
	Building	3 storey	
	Project Name	CHG Mitigation reduction	
	Project Type	Home Appliances	Family car
Assumptions	Discount Rate	8.00%	10.00%
	Annual utility Escalation Rate	5.00%	10.00%
	Maintenance Escalation Rate	5.00%	5.00%
	Escalation rate-one-time costs	5.00%	5.00%
	Study Period (years)	10	10
	Cost of Carbon	$0	$0

6.1 Resources for GHG Identification and Implementation

The home occupants are the primary resources for this proposed plan while financial resources are internally generated from personal savings to cover the implementation period of 2 years. The resources are allocated for home improvement with anticipated benefits since climate affects the energy consumption by influencing the space cooling and heating requirements. The homeowner would need the occupants to help in identifying appliances used by them for implementation. To implement GHG strategies, the homeowner will have to develop a systematic data recording that can be electronically stored as it is an ongoing process for subsequent audit and review. Financial resources for consideration includes replacing the air conditioner but it has the longest payback, Net Present Value (NPV), GHG reduction of 7.88, $659 and $7.77 respectively. Right sizing of air cooler capacity demand for each room eliminate the compressor from being 'over worked' to ensure that the British Thermal Unit (BTU) is commensurate with the cooling of 12000-15000BTU/hr as it can save up to 43 percent (Al-Mofleh *et. al.* 2009). However as Malaysia's tropical climate is hot and humid (>80%) throughout the year with average maximum temperatures occurring for about six to seven hours during the day (Rahman, 1995), alternative consideration is to install a roof wind turbine ($300) shown in Figure 4 and install R-value insulation at a cost of $600 for 100sq feet of surface area.

Figure 4: A Typical Roof Turbine Ventilator (Source: Rahman, 1994, 1995).



6.2 Prioritization of GHG Reduction

Based on the high percentage of MTCDE contribution from mobile emissions, prime consideration is to consider vehicle replacement but due to the cost, this option is subjected to budgetary constraint. Given the positive SIR of 1.32 and internal rate of return (IRR) at 15.03%, vehicle replacement should be a consideration in the next year's planning. The more worthwhile considerations are for the 15-year old home appliances. Topping the list is the water heater with positive NPV and GHG reduction, SIR of 1.63 and IRR at 19.50% yet with lowest payback of 5.23 years; it is a priority consideration for GHG reduction. However, the old freezer churns out a high negative NPV and GHG reduction despite the fact that it should be replaced with a new energy efficient 'A' rating freezer. The summarized energy and cost savings of the major GHG contributor are listed in Table 1 for projects prioritization.

Table 1: Prioritization of GHG Reduction

Simple Payback Analysis	Refrigerator	Air-conditioner	W. Machine	W.Heater	Car
Annual Savings (FY10 rates)	$594	$571	$473	$383	$5,912
Simple Payback Period (Yr)	0.72	7.88	6.34	5.23	8.46
10 Year Net Present Value	($3,416)	$659	$1,832	$2,228	$26, 359
Savings to Investment Ratio (SIR)	0.72	1.08	1.35	1.63	1.32
10 Yr Investment Cost /10 Yr MTCDE	$139.56	$186.20	$150.38	$122.70	$452.22
NPV / Total GHG Reduction	($19.41)	$7.77	$26.17	$38.94	$73.22
Internal Rate of Return	1.80%	9.68%	14.61%	19.50%	15.03%
Ranking for prioritization	No savings	4	3	1	2

In terms of affordability, 4 of these appliances can be replaced on a sixth monthly interval spread over a 2 year period. Should there be budgetary constraint; the financial resources will be allocated using prioritization where appliances with the highest GHG reduction will be tended to first. To ensure the GHG reduction plan is working as intended, the home energy consumption will have to be measured monthly and verified quarterly by audit. An annual review is necessary to ensure the GHG emission reduction is working effectively. Residential homes contribute 19 percent of GHG in Malaysia with approximately 25 percent energy losses averagely based on the 8-year study from 1997 to 2004 by Saidur *et. al.* (2007). Taking cognizance of these findings, this GHG reduction plan by 20% in absolute terms helps to narrow the gap of 25% energy loses. Consequently, it can be use as an additional measure to complement the quarterly audit and annual review.

7.0 Stakeholder Engagement

The stakeholders in this project are the home occupants who are family members. For the project to be successful there is a significant amount of educational buy-in by emphasizing on the benefits in terms of cost savings, improved living quality which are essentially part of the drivers to environmental management. Typical challenges are the lack of need for sustainability awareness. One way is to draw their interest to support and secure commitments on 3 R's and energy efficiency issues like switching off lights, appliances and minimize utilization of air-conditioning. By providing the leadership to influence the occupants to support opportunities to reduce impact of GHG, there is good likelihood of them rallying towards the common goal of GHG reduction. The success can be promulgated to visitors, friends and neighbours to create awareness of sustainable living and this process can be duplicated within the community with similar approaches towards GHG reduction planning. Using the stakeholder's manual by Krick *et. al.* (2005) and Partridge *et. al.* (2005) as guidance, persuasive messaging and incentives to occupants can be done to provide feedback. Metrics for tracking success of the plan would include CO2 emissions and energy consumption within the corresponding period e.g. $122.70/MTCDE for water heater, $452.22/MTCDE for car, $150.38/MTCDE for washing machine and $186.20/MTCDE for air-conditioning. As it involves family and friends, the homeowner has the responsibility to facilitate resources such as funding and external networking relationship to bring about positive behavioural engagement to minimise GHG emissions. For example, compact fluorescent light bulbs save 400 kg CO2/year, car pooling 1.5 kg of CO2/5km, recycling half of household waste 1,000 kg CO2/year, less beef consumption to reduce methane emission and avoiding overpacking of products 545kg of CO2 if garbage is reduced by 10%.

8.0 Funding / Financing

Home-setting GHG Reduction Plans do not attract any grant or incentive from local authorities. Under such circumstances, the mitigation strategies are entirely internally funded to achieve the GHG Reduction goals as the benefits overshadow the cost. In terms of cost, an option is to stagger implementation over a period of time and on a prioritization (by financial ranking) basis of GHG reduction as stated in Table 1. To mitigate the risk of short funding, the budgetary allocation had to be strictly enforced.

Simple Payback Analysis	**Refrigerator**	**W. heater**	**Car**	**W. Machine**	**Air-conditioner**
Ranking for prioritization	No savings	1	2	3	4

9.0 Tracking and Reporting Progress

Private home are not subjected to any mandatory GHG reporting but the homeowner will be pursuing a voluntary programme similar to TCR (2008) for the purpose of sharing within the community once the 2012 targets are met. TCR is not directly applicable to Malaysian home but the underpinning principles are relevant as they provide tools that help in calculating, reportuing, and verifying emissions annually as published in General Reporting Protocol (GRP), General Verification Protocol (GVP) and most importantly the Climate Registry Information System (CRIS) provides a convenient online GHG software to assist in reporting. Before updates are created, the entire inventory must be documented as internal record-keeping to enable an annual audit of the boundary, recalculation of procedures, assurance of data accuracy and detection of causes of uncertainty in emission factors and activity data collection. Once data is aggregated, tracking is possible to determine the progression of the intended plan by comparing the absolute target over the baseline year and thence for updating into the report. To support data tracking and updates, the homeowner will facilitate the use of Excel sheet as a GHG data information management tool although it would be nice to have a carbon software like "Enterprise Carbon Accounting" (ECA) and the Carbon Management System (CMS).

10.0 Review Cycle and Process

An internal review process provides an excellent insight on the documentary control especially during implementation of the GHG reduction plan. A simplified review process will be set up to measure if the goals are on target and if not what measures need be taken to remove the derailment. As the data management system are electronically accessible by a computer, the homeowner will conduct the review quarterly to ascertain if the estimates/calculations are working out in real terms (actual) on an ongoing basis. Success will be judged based on the evaluations of reduction of energy used and production of GHG emissions and continued reduction of emissions in absolute terms. Should there be a methodology issue; the homeowner needs to revise the plan in accordance with the updated publications of WBCSD WRI and TCR. Any deficiency in the target will be addressed in terms of ‘individual compliances’, behavioural/habit/lifestyle issues which are difficult to change.

11.0 Knowledge Management and Continuous Improvement

The information translated from the raw data is subjected to analytical processing as a form of knowledge gathering for the homeowner. From the KM perspective, the GHG related information will be filed electronically for an indefinite period for tracking and audit purposes. As part of the strategies to implement KM, these data will be kind of IT Centric to facilitate capture, access, and reuse of information and knowledge to achieve goals. The types of KM of concern to this GHG reduction project is Explicit Knowledge as the information is fully and clearly expressed or demonstrated, leaving nothing implied, knowledge that is easily stored and shared for continuous use in future. This is in opposition to the alternative approach of Tacit Knowledge where concepts are mainly understood without being openly expressed, acquired through experience or memorization. Being a home GHG Reduction initiative, the homeowner is responsible for storing and retrieving information electronically from the computer as and when needed for purposes of analysis, tracking and reporting. Using thetraining from the E116 course in defining GHG Reduction Goals, and an awareness of the Supporting Standards and Policies are sufficient to develop continuous improvement on this simple home GHG Reduction Plan. However, to facilitate effective sharing with the local community, the homeowner has plans to undergo skills development training related to GHG certification programme. In addition, to ensure that the occupants get involved in and support the GHG plan, the homeowner will provide basic training on how to perform an energy inventory audit. This is particularly important for new occupants so that they will be aware of the plan from the onset of joining the family home. After all, this project will not only be confined to reporting purposes but it also involves lifestyle or behavioural changes as a means to meet the GHG Reduction Goal in the longer term.

12.0 Conclusion

This document is designed as an action plan within the home setting to increase the awareness of the occupants to become environmentally conscious by reducing GHG emissions for the benefits of the community. Prior to GHG planning process, an energy audit must be conducted extensively to determine energy consumption. The GHG reduction process requires lots of manual work for data compilation once the plan is conceived for implementation as availability of raw data is crucial for the estimation process. Based on the summarized data, conversion is made to CO2e emissions which are then used for conducting reduction planning.

The current project can be broken down into three main phases. The first phase involved energy audit for data gathering. The second phase calculated CO2e emissions based on the WBCSD WRI (2004) Greenhouse Gas Protocol Accounting Standard. In phase three, prioritizations were presented using the Harvard LCC tool with a discount rate of 8-10% for estimating purchase of new home appliances and compact fuel efficiency family car. The tool provided mitigation strategies to purchase inverter based (20%) energy saving in the refrigerator, air-conditioner, washing machine and electronically controlled water heater. The consideration for replacements was determined using SIR ranking and in terms of budgetary affordability; these appliances could be slotted for replacement on a six monthly basis over a 2 year period.

From the results, it appears that GHG Reduction Plan certainly helps to reduce CO2e emissions by lowering energy usage while the SIR using the Harvard LCC tool, provided a formulae to mitigate strategies through pprioritization based on demonstrated savings in achieving GHG reductions goals. However, the success of this plan hinges on the completeness of energy data collection, accuracy of billing data as well as the accuracy in estimating/quantification of loads. There are some important lessons to be learned in GHG reduction planning process. Firstly, the recruitment of participants in this plan is crucial in terms of access/identifications to all mobile appliances in each occupant's/visitor's room. Secondly, as the estimation was focused only on common areas/activities the results may not be fair representatives of energy consumed per household or per capita GHG emissions within the same area. Additionally, energy usage is a function of ambient temperature, therefore demand is a characteristic of load during low or high peak usage. In this regard, KM is critical to the long term success of GHG planning as KM serves as the backbone in driving the environmental goal for the benefits of the community. Consequently, KM approaches must be tailored to the select individual that can redirect the information to the community as a process for future improvements.

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