An Evaluation of Personal Greenhouse Gas Calculators

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Abstract

Personal greenhouse gas calculators (PGGC) are important tools to raise awareness of the impact of personal behaviour on carbon dioxide emissions. Per capita, Australians are the highest emitters of greenhouse gases in the world and the task for them to reduce emissions to sustainable levels will be particularly challenging. This paper reviews six PGGC promoted in Australia and evaluates them for their consistency. The emissions for an individual currently practicing a modest green lifestyle are calculated and compared. Emission calculations were found to differ by an order of magnitude in some cases. It was also found that users of PGGC are not adequately informed about the limitations of the calculators. The adoption of modest and radical green lifestyles reduced greenhouse gas emissions to 83% and 53% of the average Australian, indicating that behavioural changes by consumers alone will be insufficient to reduce emissions to sustainable levels.

1. INTRODUCTION

Global warming, resulting from the increase in atmospheric levels of CO_2, is arguably the most serious environmental problem faced by humankind. Massive reductions in global emissions of carbon dioxide are required merely to stabilize ambient concentration levels to manageable levels. Reductions in global greenhouse gas emissions of about 60% are required if atmospheric concentrations equal to those of pre-industrial levels are to be achieved (Turton et al., 2002). Endorsement of the need for these deep cuts has come from both the scientific community and world political leaders. Australia's Chief Scientist, for example, said in 2004 that he saw the need for "enormous reductions – 80 per cent by the end of the century" and "fifty per cent by 2050" (Peatling, 2004). To achieve such reductions will require actions to be taken at all levels of society (government, industry and household) ,particularly in the industrialised countries. Recent calculations indicate that on a per capita basis, Australians are the highest emitters of greenhouse gases in the world, producing 27.2 tonnes of $CO2_e$ per person (Turton, 2004). The task for Australians to reduce emissions to equitable and sustainable levels will therefore be particularly challenging.

It has been calculated that the consumption of goods, services and direct energy use by Australian households is responsible for approximately 58% of the country's total emissions (Lenzen, 1998). This analysis suggests that individuals should be able to reduce their greenhouse gas emissions significantly if they modify their behaviour in terms of the consumption of goods and services at the household level. In fact, various studies, both in Australia and elsewhere, have demonstrated in theory that individuals can achieve significant reductions in personal greenhouse gas emissions, if they change their behaviour and adopt conserver lifestyles. Christensen (1997) analysed the impact of lifestyle on the environment using a life-cycle assessment to determine the energy, carbon dioxide and sulphur dioxide emissions for four hypothetical families with the different consumption patterns and ways of living. Two conserver lifestyles were imagined. In the modest green lifestyle, the family does not own a car but travels 15,000 km per annum using public transport. Heating and electricity are supplied by a coal-fired co-generation power plant. The family eats an average quantity of meat, but it is organic in origin. In the radical green lifestyle, on the other hand, it is assumed that all travel undertaken by the family is by bicycle or on foot. Electricity and most of the energy for heating their home is derived from renewable energy sources. The family eats less meat and more vegetables than average, and all of this food is organically produced. Compared to an average American lifestyle, the adoption of modest green or radical green lifestyles reduced the carbon dioxide emissions by 40% and 79% respectively. Weber and Perrels (2000) modelled the life style effects on energy demand and related emissions for various household types and sizes in West Germany, France and the Netherlands. Four lifestyle scenarios were examined theoretically. Two of these scenarios addressed the goal of sustainability. In the first of these scenarios, energy and associated emissions were to be reduced through technological breakthroughs, but in the second scenario, the driving force was reflective consumption. In this latter scenario, the 'goals of environmental quality and social justice take a pre-eminence, so that economic growth is no longer the predominant social objective'. This shift in emphasis enables emissions to be maintained at or below 1990 levels over a 20-year period.

Lenzen and Dey (2002) analysed the impact of environmentally motivated spending in relation to diet, transportation, electricity supply, hot water system and appliance repair on greenhouse gas emissions in Australia. Adopting a diet based on Department of Health data rather than that currently consumed by most Australians can reduce greenhouse gas emissions attributed to food consumption by approximately 20%. Opting for a mix of transportation (bus, train, hire car and taxi) to reduce air travel and private car use produced a 31% reduction in emissions compared to that generated by the current Australian domestic transport pattern. Reductions in emissions of 74% due to household electricity use are possible, if this energy is generated by a renewable source. The opportunity for such a reduction is possible if a family opts for Green Power electricity, which is offered by most Australian suppliers. Two examples of repairing consumer items (a car and a washing machine) were analysed to determine the impact of this behaviour rather than opting for replacement with a new item. Fifty percent reductions could be achieved if a 10-year old car was repaired for a further ten years of life, compared to the emissions generated by the manufacture of a new vehicle. Savings of 18% in greenhouse gas emissions, compared to those generated when manufacturing a new $800 washing machine, were achievable if $400 were spent on repairing the machine over its 10-year lifetime.

If an individual decides to calculate their greenhouse gas emissions, they will need to use a personal greenhouse gas calculator (PGGC). There are now numerous Australian and overseas PGGC that can be downloaded from the Internet. Users, both professional and non-professional, might legitimately question the accuracy and consistency of these PGGC. It is also important from an educational perspective that the users of a PGGC, particularly non-experts, are informed adequately of the limitations of a particular calculator, so that the results may be adequately qualified by the user where necessary. How well do PGCC perform this role and what sort of lifestyle might produce the level of changes required for climate stability? This paper attempts to provide some insight to these questions using six PGGC currently being promoted in Australia. To do so, the estimates of emissions by the various calculators are compared to test for their consistency using actual household data collected over an extended period from a consumer practising a modest green lifestyle. The limits to the reductions in emissions that can be achieved by adopting further conservation measures are then investigated by re-calculating emissions using the most detailed of the PGGC.

This paper begins by classifying the two basic types of PGGC and describing their differences. Six Australian PGGC are then reviewed, with brief explanations of the components of lifestyle covered, and how the input information is used. These differences are summarised in a comparative table. The profile of the modest green consumer is then presented and actual household consumption data from this consumer, collected over a one-year period, is tabled. This data source is then used to estimate and compare the individual’s carbon dioxide emissions using the six PGGC. The emissions from this consumer are then recalculated when further behavioural changes, reflecting the adoption of a radical green lifestyle, are assumed. The results are discussed and some conclusions drawn about the use of PGGC and their ability in assist in reducing personal greenhouse gas emissions.

2. PGGC TYPES

Numerous environmental organisations and agencies now promote various calculators on the Internet. In addition to those later reviewed in this paper, some of these calculators include: those hosted by NASA and the Environmental Protection Agency in the U.S; the 'One-Tonne Challenge' in Canada; and 'Climate Care', 'Carbon Balanced' and the 'Carbon Neutral Company' in the UK. All these tools can be categorised as 'direct' and 'total energy' calculators and may be generally distinguished as follows:

Direct Energy Calculators

The overwhelming majority of PGGC assess only the direct energy consumption of the user. Direct energy includes that used for car travel, heating and cooling, lighting and general power requirements. In other words, it is the energy that comes directly from the petrol we put in our cars, and the energy supplied by electricity and gas utilities. Most Australians believe that they are only personally responsible for their use of direct energy and this represents their main greenhouse gas contribution (AGO, 2002a). Lenzen (1998) has shown that direct household energy use is responsible for approximately 11% of Australia's total greenhouse gas emissions.

Total Energy Calculators

Energy is used in the provision of every item and service that is purchased. While this energy use may not be obvious to the individual at the point of consumption, an analysis of the history of the processes to deliver that item or service will reveal a quantity of direct energy has been used. This energy is known as indirect or embodied energy. Techniques are now available which enable the energy used in the provision of all goods and services to be determined. Most Australians do not consider this indirect energy use when assessing their impact on the environment. Focus groups and telephone surveys were used in Australia in 2002 to measure public awareness of greenhouse issues and determine the implications for 'Cool Communities', a community engagement program (AGO, 2002b). One finding was that "almost no one had knowledge of how much households contribute to the greenhouse effect, a result revealed by both the survey and focus groups". Even those investigating Australian attitudes to climate change and greenhouse gas emissions appeared not to appreciate the link between total consumption and emissions because there is no mention of indirect energy use in the dialogue with survey participants (AGO, 2002a). Lenzen (1998) has shown, however, that the energy embodied in all the goods and services, which are consumed by Australian households, is responsible for 47% of the country's greenhouse gas emissions.

3. EXAMPLES OF AUSTRALIAN PGGC

At least six PGGC are currently being promoted in Australia to encourage individuals to assess and presumably reduce their emissions. Brief details of these PGGC are presented below, identifying the type of calculator, the input information required from the user and the output information provided. A summary of the six calculators is given in Table 1.

The Greenfleet Calculator (Greenfleet, 2005)

This is a direct energy calculator. It calculates greenhouse gases generated by car and air travel, as well as the direct energy use in the home. The household postcode and occupancy level are required. The user is given two calculation options. The first provides a 'quick' estimate of emissions and the second gives a more 'detailed' and accurate assessment. In the former, actual energy use is not required and the user chooses only fuel type, number of cars and the number of air flights made. In the latter option, the type of fuel and annual costs or distance travelled is used to calculate vehicle emissions. For air travel calculations, domestic, short and long international flights are differentiated. Two levels of impact from air travel can be calculated. The first calculation is based on fuel use alone, while the second calculation option includes the additional impact of releasing these gases at high altitudes rather than at ground level. In addition to greenhouse gas estimates, the number of trees required to offset these emissions is given as an output.

The Australian Greenhouse Calculator (VicGovt, 2005)

This calculator is a collaborative effort of a number of agencies and is hosted by the Victorian Government as part of its greenhouse strategy. It is primarily a direct energy calculator, but it does include emissions generated by household waste. It also provides 'quick' and 'detailed' levels of calculation, although at the time of assessment the latter could not be accessed. (Note that definitions of 'quick' and 'detailed' vary greatly between different PGGC). The user's emissions can be compared with both 'green' and 'typical' consumers in each state of Australia. Compared to some calculators, the level of detail in the 'quick' version is extensive. For example, the user must estimate the number of baths taken each week, the number of low flow showerheads fitted in the house, the number of hours of TV and computer use per week etc. Output from the 'quick' calculator is also detailed. In addition to greenhouse gas emissions, the user can view the levels of other pollutants (NO_x, CO, VOCs, particulates and SO_x), which they have generated.

The SMRC Calculator (SMRC, 2005)
This calculator is promoted by the Southern Metropolitan Regional Council in Western Australia. It is a direct energy calculator and the user is required to supply similar information to the 'detailed' version of the Greenfleet calculator. Daily electricity and gas usage figures are required. Total and green waste quantities must also be estimated. In accompanying notes, the calculator acknowledges indirect energy use and provides an estimate of average household indirect emissions of 48 tonnes of CO_2 per annum.

The StinkOmeter (ISA, 2005)
This is a total energy calculator developed by the multi-disciplinary Integrated Sustainability Analysis (ISA) research team at the University of Sydney. The greenhouse gas calculations are based on the work of Dr Manfred Lenzen. His contribution to the quantification of the indirect energy component of goods and services is based on an analysis of the Australian economy using the input-output analysis technique (Lenzen 1998). Use or reference to his work is found in several Australian PGGC. The calculation of the greenhouse gases associated with consumption requires the user to enter the dollar values of all expenditure in different categories. Food, for example, is broken down into meat, dairy, grain, sugar, fruit and vegetable products. Emissions associated with the use of services such rates, telephone and insurance are calculated separately and are assumed to generate approximately half the level of emissions as the purchase of goods. The single output is tonnage of greenhouse gas per annum, but the user is encouraged to compare their emissions with the average world citizen and to the level which is believed to be sustainable.

Planet Slayer (ABC, 2005)
This is a total energy calculator, but quick and entertaining to use. The ABC Science Unit hosts the website and has named the tool as 'Professor Schpinkee's greenhouse calculator'. It requires the user to answer 11 questions about car and air travel, size of house and energy bills. Other questions reflecting the indirect energy consumption including the amount of meat consumed and the amount of money spent per annum. The user is able to differentiate between the money spent on ethical and environmental goods and services, and that spent on everyday items. The output is given in terms of tonnes of greenhouse gas and (entertainingly) as an exploding pig, which informs the user how many years they would be permitted to live at their current rate of emissions before using up their share. In the accompanying notes, the calculator stresses that direct energy use only contributes about 20% of an individual's emissions. The remaining 80%, on average, comes from the consumption of goods and services. According to the calculator, 1.6 kg of greenhouse gas is generated for every dollar spent.

Greenhome (ACF, 2005)
This total energy calculator poses thirteen questions to the user, which reflect their use of energy and water, as well their expenditure on food, goods and services. The calculated results are compared to the national average in terms of water usage, land requirements and greenhouse gases. The results are also compared to the levels required for a 'sustainable' Australia. The user is invited to find out how the calculator works and to view appropriate background information. Incentives are offered to encourage users to further reduce their impact. This calculator is based on the work of the multi-disciplinary ISA research team at the University of Sydney.

4. MODEST GREEN CONSUMER PROFILE

In order to test the consistency of PGGC and to calculate the level of emissions generated by a lifestyle believed to generate low carbon emissions, actual consumption data was been collected over a 12-month period for an individual, who describes himself as a modest green consumer. This information has been used as input data for the six PGGC so that results can be compared and to determine whether the level of emissions from the modest green consumer represents a sustainable level. The range of input data required reflect the differences in perspective and objectives of the various PGGC and not all the following information is required by each of the PGGC.

The modest green consumer is aged between 50 and 65 years and lives alone in 114 m2 house located in a small town with between 1000 and 10,000 residents. The nearest capital city in Australia is Melbourne. His annual expenditure on food, goods and services is shown in Table 2. The modest green consumer does not own a car and uses public transport and a bicycle for most of his travel requirements. Table 3 shows the distances travelled in each of the various modes of transport used.

To conserve energy, the modest green consumer has installed a gas-boosted solar hot water service and a grid-connected solar electric system on his house. As a result, his annual energy use for hot water and electricity is low (Table 4).

Table 1 Summary of characteristics of a selection of Australian PGGC
(It has been assumed that emissions are $CO2_e$ although this is not explicitly stated in most PGGC)

PGGC	Type	Inputs	Outputs
Greenfleet	Direct	Fuel usage Heating type Distances travelled	$CO2_e$ emissions (tonnes) Number of trees
Australian Greenhouse	Direct	Appliance types Transport usage Fuel usage Waste management Trees planted	$CO2_e$ emissions (tonnes) Annual energy costs ($) Pollution data (kg a-1) Table report
SMRC	Direct	Fuel usage Waste generated Distances travelled	$CO2_e$ emissions (tonnes)
StinkOmeter	Total	Total expenditure details Fuel usage Waste generated Distances travelled Trees planted	$CO2_e$ emissions (tonnes)
Planet Slayer	Total	Expenditure estimates Distances travelled Fuel usage Diet Household size	$CO2_e$ emissions (tonnes) Atmospheric 'share' (years)
Greenhome	Total	Expenditure estimates Distances travelled Fuel usage Diet Household size	Water use Land requirements $CO2_e$ emissions (tonnes)

Table 2 Annual expenditure on food items, goods and services

Item	Expenditure ($)
Meat products	0
Dairy products	398
Fruit and vegetables	1204
Bread, flour and cereals	666
Margarine, oil and fats	181
Sugar, confectionery and all other foods	593
Beverages	1097
Meals out	2432
Goods (excluding food) - clothing, footwear, TV, books, paper, magazines, HIFI, video, household chemicals, cars, furnishing, appliances, recreational goods, construction materials.	1782
Services (excluding transport) - mortgage, rent, rates, phone, mail, insurance, personal services, banking, accommodation, movies, concerts, sporting events, etc.	10984
Total	19337

Table 3 Annual distances travelled in various transport modes

Transport Mode	Distance travelled (kms)
Bicycle	1689
Bus and coach	3091
Train and tram	6082
Car (2 occupants)	3297
Domestic air	950
International air	0
Total	15109

Table 4 Household Electricity and Fuel Use

Energy Type	Usage
Electricity (conventional)	360 kWh
Electricity (renewable energy)	16 kWh
Natural gas	6906 MJ

5. RESULTS AND DISCUSSION

The data from the modest green consumer profile described above has been used to calculate the greenhouse gas emissions using each of the PGGC described above (Table 5 and Figure 1). The results indicate that there is an order of magnitude difference in the emission figures generated by the PGGC, which have been evaluated. For the user with little or no background knowledge of the complexities of carbon emission calculations, such apparent contradictions will not only be confusing but may also be counter-productive. Such a user could easily become cynical about the usefulness of PGGC if the estimates of their annual greenhouse gas emissions appeared to vary from 2.5 tonnes to 26 tonnes.

The inaccuracy of the quick 'total' calculators evaluated is also demonstrated by the discrepancy between the estimates of emissions from the StinkOmeter, Planet Slayer and Greenhome versions. Assuming that the detailed version (the StinkOmeter) is the most accurate PGGC, the estimated emissions from the 'quick' versions (Planet Slayer and Greenhome) are only 30-50% of the estimates of the detailed version. In this case, the underestimate may generate a false sense of complacency for any user trying to reduce emissions.

Assuming as before that the emissions estimated by the StinkOmeter are the most accurate of all the PGGC evaluated, the effect of adopting many measures advocated to reduce emissions can be seen. In this instance, the emissions of the modest green consumer actually appear to be greater than the Australian average. According to the StinkOmeter, emissions from the average Australian are 24.6 tonnes per annum. This indicates that on face value the modest green consumer exceeds this level by about 6%, despite adopting the low impact lifestyle.

Table 5 Predicted greenhouse gas emissions for the modest green consumer

PGGC	Emissions (tonnes)
Greenfleet	Quick 5.7 Detailed 2.5
Australian Greenhouse	Quick 2.9
SMRC	2.8
StinkOmeter	26.0
Greenhome	7.4
Planet Slayer	11.0

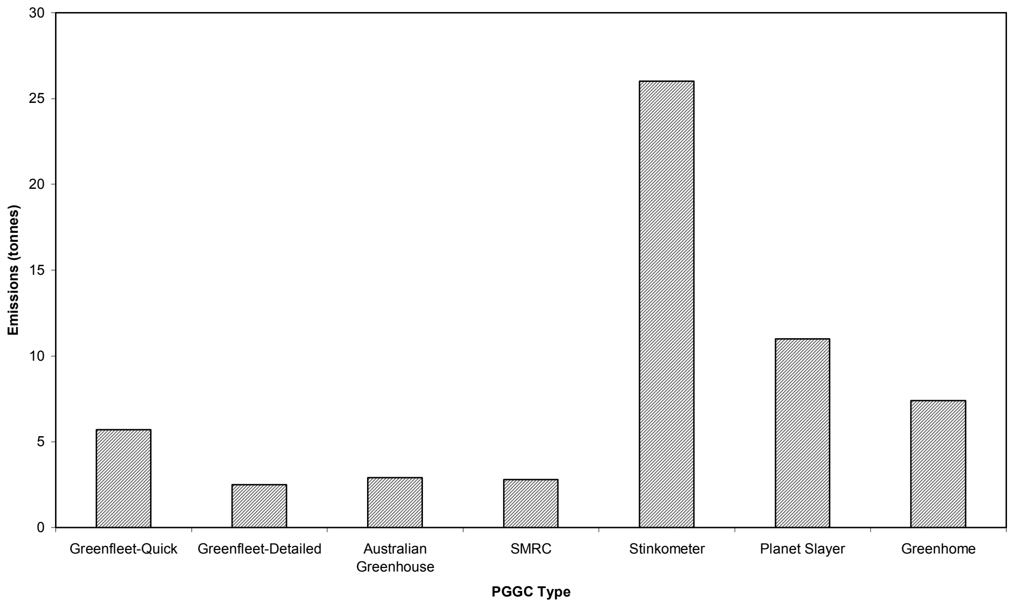

Figure 1 Comparison of predicted greenhouse gas emissions for modest green lifestyle

One major problem with total calculators based on input-output analyses is that emission coefficients will change over time due to inflation and changes in energy intensity (energy consumed per unit of output). Over time the effect of inflation will be to increase the apparent expenditure on goods and services. Likewise over time, most industrialised countries have reduced the energy intensity of their economies. Therefore to some extent the energy used to produce household consumables should reflect any decline in aggregate energy intensity. The StinkOmeter is based on 1995 data. Over the following ten years the consumer price index increased by approximately 25% (ABS 2005). Over eight years in the 1990s, aggregate energy intensity in Australia declined by 9% (ABS 2002). If these two figures are used to adjust the predictions of the StinkOmeter, then the predicted emissions from the consumer with a modest green lifestyle are reduced to 20.4 tonnes or 83% of the Stinkometer's estimate of the average Australian.

The limits to the reductions in CO_2 emissions currently achievable through the changes in personal behaviour in Australia can be determined by recalculating the emissions assuming further lifestyle changes. Aspects of the modest green lifestyle, previously analysed, were amended to reflect an even more radical green lifestyle. Some aspects of this lifestyle are similar to those described by Christensen (1997). Other changes have been incorporated, however, to reflect a big reduction in personal consumption. The radical green lifestyle would be similar in many respects to that advocated by Trainer (1995), who argues that a simpler lifestyle is required in industrialised countries because of resource limitations and the environmental consequences of fossil fuel use.

The following assumptions were made to reflect a radical green lifestyle:

- Travel is restricted to only that which can be made by bicycle or walking. Assuming the amount of bicycle travel increases to approximately 100 km per week, emissions for 5000 kms were calculated.
- A vegan, rather than an ovo-lacto, diet is adopted. This change means that there will no longer any emissions associated with dairy food consumption. It has been assumed, however, that a similar expenditure on other foods has been made instead and that this consumption generates 1.4 kg of CO_2 per dollar spent.
- The money spent on food and drinks consumed outside the home, i.e. 'meals out', is reduced by 90%.
- Expenditure on goods is reduced by 75%
- Expenditure on some services e.g. rates, telephone, insurance is reduced by 50% because it is assumed that the house will be shared with one other person.
- Emissions from conventional electricity are reduced to zero because of the adoption of Green Power.

Assuming the above assumptions, the emissions for a deep green consumer have been calculated to be 13 tonnes i.e. a reduction of 47% compared to the Australian average. While this figure represents a significant reduction from present levels, it stills falls short of the estimated global average reduction required to achieve climatic sustainability. In terms of global equity in emissions, 13 tonnes is still approximately four times higher than that estimated to be an equitable and sustainable level for everyone on the planet (Lenzen and Murray, 2001). This finding therefore indicates that despite significant changes in personal consumption this alone will not be sufficient to make the required reductions in emissions in Australia. Other changes such as an increase in energy efficiency and a reduction in the carbon intensity of the energy used by Australia's commercial and industrial sectors will be required.

6. CONCLUSIONS

A selection of PGGC promoted in Australia has been evaluated to test the consistency of their predictions of personal greenhouse gas emissions. On face value, estimates of emissions can differ by an order of magnitude for the same user. These large differences occur because some PGGC only calculate emissions based on direct energy use, while others also include the emissions associated with energy used in the production of goods and services. None of the direct energy calculators inform the user of the PGGC's limitations and omissions and therefore the results are misleading. Even between direct energy calculators, differences between 'quick' and 'detailed' calculators can exceed 100%. Predictions from calculators using national economic data can be significantly affected by inflation and changes in energy intensity over time.

Using the most detailed of the total energy calculators and adjusting for inflation and changes in energy intensity, the emissions of a consumer with a modest green lifestyle were determined. His emissions were calculated to be approximately 83% of the average Australian, based on an annual carbon dioxide emission rate of 24.6 tonnes per capita. This reduction was achieved by not owning a car, adopting a vegetarian lifestyle and using solar technologies. The limits to reductions in CO_2 emissions achievable through changes in personal consumption were explored by assuming further behavioural changes. By adopting a radical green lifestyle, emissions of 13 tonnes per annum were calculated, which are 53% of the average Australian. These findings indicate that changes in personal behaviour alone cannot currently achieve the average level of emission reduction estimated to be required to achieve climatic stability at twice the pre-industrial levels. Changes at a structural level, particularly by improving energy efficiency and in reducing the carbon intensity of the energy used by the commercial and industrial sectors in Australia will be required to achieve the level of reduction required.

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