Reducing our carbon footprints – feeling cool and being healthy.

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CONTENTS

Introduction

This booklet is about understanding global warming and discovering the good feeling of reducing our carbon footprints. It aims to show:
i. The causes of global warming, sources of greenhouse gases and how to emit less of them.
ii. How we can adopt consumption habits that reduce our carbon footprint, give us better health and the satisfaction of making a difference.

Global Warming and its Causes

Global warming i.e. 'climate change' is caused by increasing atmospheric concentrations of greenhouse gases emitted by human activities, primarily combustion of fossil fuels.

Greenhouse gases (GHGs or 'carbon emissions') in the atmosphere are heating up our planet, causing extreme climate events. Carbon emissions are expressed in tonnes of carbon dioxide equivalents (t CO_2e). The contribution of each GHG to global warming is: carbon dioxide (CO2) 76%, methane 16%, nitrous oxide 6% and fluorocarbons 2%. (See Appendix 4).

Emission of GHG's is occurring at a rate that is double the capacity of the Earth's oceans and forests to assimilate them. The concentration of CO2 in the atmosphere in 2020 is 413 ppm and has been rising at about 3 ppm per year (NOAA, 2020). At this rate it will reach 450 ppm in 2032. This is the threshold concentration at which 97% of climate scientists agree global warming will reach 2 deg. C. and climate change will be irreversible. Droughts, bushfires, floods and sea level rise will be increasingly catastrophic.

The sources of anthropogenic greenhouse gas emissions globally are: *(Ref: US EPA, 2020)*

- *Electricity and heat production 25%*
- *Agriculture and land clearing 24%*
- *Industry 21%*
- *Transport 14%*
- *Buildings 6%*
- *Other energy 10%*

Global Climate in 2020

Global warming has increased unabated to 1.2 deg. C above pre-industrial times, mostly in past thirty years. Unprecedented climate events are now occurring regularly. Wildfires have devastated Australia and California in 2018-2020 while devastating flooding has occurred in most tropical nations and parts of Europe. Coastal erosion and shoreline retreat is happening nearly everywhere due to rising sea levels. Some Pacific Islands will soon have to be evacuated.

International carbon abatement agreements

The **Kyoto Protocol (KP)** was ratified by the US, Australia and most other nations (162 in all) in Feb 2005. Many nations introduced **carbon pricing schemes** - carbon taxes or 'cap and trade' emissions trading schemes (ETS). For example the European ETS covers 31 countries and has been operating since 2005. Australia introduced an ETS in 2011 but it was repealed in 2014. The US also does not have a national carbon price though many US states do. China has a carbon price in some regions.
The '**Paris COP Agreement'** has replaced the KP. It was by signed and adopted by 174 nations in 2016. Signatory nations have developed and pledged their own legally binding emissions reduction targets, for example Australia's is 26-28% by 2030. The adopted version of the Paris Agreement stated that parties will also "pursue efforts to" limit the temperature increase to 1.5 °C. The 1.5 °C goal will require zero carbon emissions sometime between 2030 and 2050 (Wikipedia, 2020). Tragically, concerted propaganda campaigns against climate action funded by large fossil fuel corporations and executed by right wing climate denialist media, chiefly the Murdoch world-wide media empire has resulted in a decade of inaction by some governments. The US, under the reactionary Trump Republican government plans to pull out of the Paris COP in 2021.

In Australia, a Labor government enacted legislation in 2010- 2012 that effectively reduced carbon emissions. The Carbon Pollution Reduction Scheme – a carbon price and Mandatory Energy Efficiency Audits for the 200 largest corporate emitters – lasted 3 years. It was repealed by a climate denying reactionary Liberal-National government.

The issue of emissions from the developing world is a vexed one. The poor countries in particular in Africa need the assistance of rich countries in clean development to reduce poverty. However China and India have expanding economies, increasingly affluent populations and rapidly increasing carbon emissions and must also work to limit their emissions and be part of global efforts. China has now surpassed the US as the world's highest emitting nation.

Why do our carbon emissions matter?

To avoid catastrophic global heating, greenhouse gas (GHG) emissions must be reduced to net zero - i.e. greenhouse gases emitted = that assimilated by the biosphere - by 2050. To achieve the 'net zero carbon by 2050' target - which has already been adopted by many countries - the carbon footprint of everyone in the world would need to fall to 1.5 t CO2e. This is similar to that of many African countries where people do not drive cars.

The higher carbon polluting countries such as the US Canada and Australia emit about 20 tCO2e per capita, about half - 11-12 t CO2e per person - is from household consumption, i.e. our personal carbon footprints. Composition of carbon emissions from a typical household of 3 people is summarized in Table 1 below. CO2e pollution is also an indicator of other human impacts such as resource depletion, land footprint and toxic air pollutants.

The high consumption lifestyles most of us have become accustomed to have been the main cause of the heating world we now find ourselves in. If we keep on emitting as we have been for the last 80 years, many worsening climate disasters will be borne by our children and hundreds of future generations. Eventually Earth's climate would become unlivable. Knowing our consumption habits are the main cause of the problem can make us lose hope. But there are many things we can do to solve the problem, individually and with others.

Don't wait for governments. Let's just do it!

Attaining the goal of 1.5 tCO2e per person by 2050 will entail many changes to our consumption habits. But we can do it while actually increasing our quality of life.
We don't have to wait for Governments to solve the global heating problem. By making informed decisions in all aspects of our home and transport energy consumption, the average person can at least halve their carbon emissions and become low carbon impact. As more people reduce their own carbon footprints and vote accordingly, political parties will legislate for climate action.

Table 2 and Figure 1 below illustrate how personal carbon emissions relate to consumption habits. We all need to change some habits. But for equity and fairness, it is high emitting individuals in all nations, with carbon footprints several times higher than others, who bear most obligation to change. Is it fair that some can do so much more than others to degrade Earth's essential shared common resource - our atmosphere and climate?

Table 1. Break-down of emission sources from an average household in a developed nation

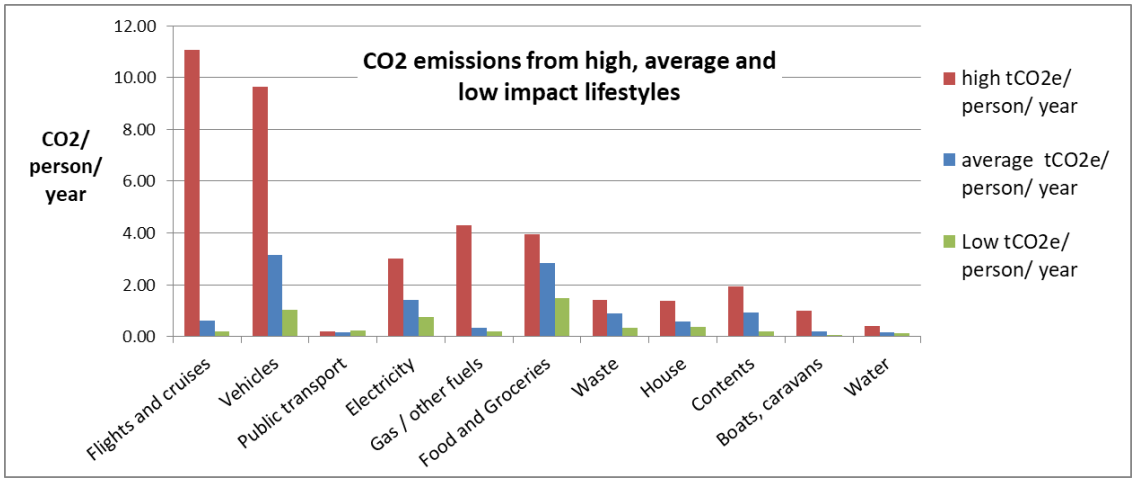
About 2/3 of our carbon footprint is from consumption of home energy, food and goods and 1/3 from transport. About 45% is directly from fuels and electricity and 55% is embodied.

Fuel and electricity carbon emissions	
Air/sea travel	5%
Car travel (fuel)	21%
Public Transport	2%
Electricity	14%
Other fuels	3%
Embodied carbon emissions	
Cars	5%
Food and groceries	25%
Waste	8%
Water	2%
Housing	5%
Possessions	10%
TOTAL	**100%**

Table 2. Analysis of annual carbon emissions of high, average and low carbon impact lifestyles

b	**High (38.3 t)** *household of 2*	**Med. (11.3 t)** *household of 3*	**Low (5t)** *household of 2*
Flights and cruises *(pp)*	6,000 km luxury cruise, 40,000 km business cl. flights	5,000 km economy class flights	2000 km economy class flights
Vehicles *(km/year)*	25,000 km: large SUV/ car, all driver-only trips	20,000km: med-large cars, some shared trips	20,000 km: light car, all shared trips, E-bikes, E-m/ cycle
Public transport*(pp)*	5000 km each	3300 km each	5,000 km each
Electricity *(home)*	10000 kWh pool, ducted A/C	7000 kWh average appliances	1500 kWh efficient appliances
Gas / other fuels	central heating 3000 L oil	heating 1500 kWh gas	LPG 40 kg; wood 0.8t
Food, Groceries	lots of red meat; processed	typical diet incl. meats	mainly vegetarian no red meat
Waste	lots of packaging	recycles packaging	minimal waste; recycles
Housing	very large 300 sq. m (for 2)	large 185 sq m (for 3)	80 sq m unit (for 2)
Contents *(items)*	V. high quality, many if each	average quality, 1-2 of each	basic , 1 of most items
Boats, caravans	large boat and caravan	small boat and caravan	none
Water	600 Kl	400Kl	200 Kl

Figure 1. Per person carbon emissions from three lifestyles – analysis using GHG-Energy Calc



What should our carbon footprint goals be?

In 2020, a carbon footprint of **5 t CO2e per person per year** is an achievable personal goal for all people living in developed countries. Average CO2e emissions of people in many European countries e.g. Sweden, Spain and France are already below this figure. Being part of the change is the best way to feel empowered and influence others to do the same. The Author and his wife, who live in an outer suburb in Australia have reduced their personal CO2e emissions from 10 tonnes to 5 tonnes per year although they still travel 20,000 km/ year, have a light car and eat small amounts of white meats. We feel good in the knowledge that we are helping the Earth and have better well-being from healthier eating habits and more exercise.

By 2030, if electricity is 90% renewable, it will be possible to reduce our carbon footprint to **3 t CO2e per year** and still have a modern urban lifestyle. All people will need to:

- travel mostly by electric bus, train, E-bicycle or electric micro-vehicle(s),
- eat a mainly vegetarian diet,
- live in super-efficient housing in terms of energy use, space and materials,
- curtail fossil fueled flights and ocean cruises.

This is achievable globally by 2030 if there is the community and political will to do it.

By 2050, every one of us in the world will need to reduce our personal CO2e emissions to **less than 1.5 t CO2e.** This will necessitate the world's high per capita emitting populations making the changes to their lifestyles summarized in 2 above. In the same time-frame, radical changes to all energy and supply chains will have to be made by all corporations and governments:

- **Energy** - all electricity grids will have to be converted to >90% renewable energy. All fossil fuels replaced with renewable electricity, hydrogen and solar heat. This achievable now for no more cost: https://cleanenergymodelling.com.au/powerbalance2/
- **Food** - Low emission cropping, minimizing packaging, localizing food production and curtailing methane emissions from ruminant animals. This is achievable with today's technologies and need not involve significant increases in the cost of food.
- **Resource extraction**, by using > 90% renewable energy and curtailing fossil fuel extraction.
- **Goods manufacturing** - by converting >90% of processes from fossil fuel to renewables, localizing supply chains, curtailing air freight and powering ships by wind and hydrogen.
- **Infrastructure and housing**, such as homes, roads, railways and public buildings by reducing scale and mass, near zero emissions production of steel and concrete and maximizing use of wood in buildings.

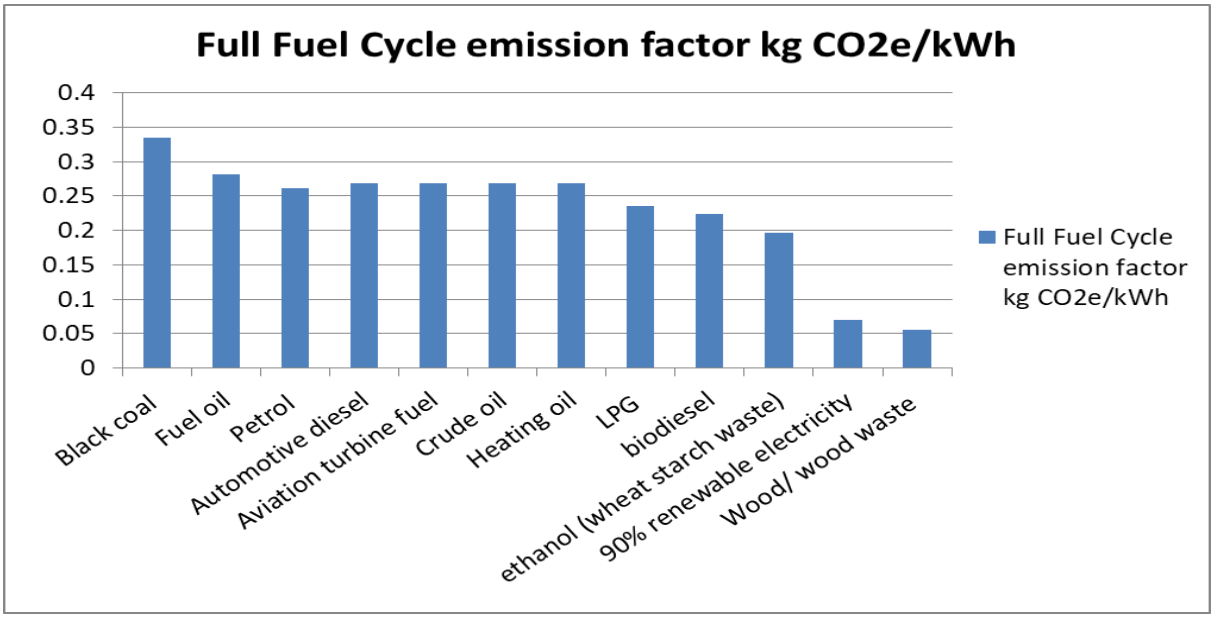
A good first step to reduce carbon footprint and energy consumption is estimating our carbon emissions. This can be done in about 30 minutes using *GHG-Energy Calc*. Download from: cleanenergymodelling.com.au

GHG Energy Calc is designed to encourage self-auditing of energy use and carbon footprint for households and small businesses. It estimates:

- ***Direct energy and CO2e*** *emitted from fuel and electricity we use.*
- ***Upstream energy and CO2e*** *is emitted from the extraction/ refining of the fuels and generation of that fuel and electricity.*
- ***Embodied energy andCO2e****, which are from the production and manufacture of the food and goods we consume.*

Note: Direct + upstream = 'full cycle' emissions.

Figure 2. Carbon emissions per unit of energy for energy sources



Will 'peak oil' slow oil consumption and help prevent catastrophic global heating?

Oil consumption is a major contributor to global carbon emissions. Over 50 % of the world's oil reserves have already been used. The 'peak oil' theory was that production rate will 'flatten' and decline as the remaining reserves become more difficult and costly to extract. The prices of petrol, diesel, jet fuel and petroleum products such as plastics, fertilizers would then rise. However, this has not happened. Fossil fuel corporations aided by rogue governments continue to increase production and flood markets, delaying price increases.

To avoid catastrophic global warming, most remaining coal, oil and gas reserves must stay in the ground regardless of whether or not they are economic. Starting with the most unnecessary and inefficient uses, oil consumption needs to be drastically reduced. Cheap renewable electricity for charging electric vehicles and producing hydrogen by electrolysis is already being used to replace oil and gas in transport and coal in the steel industry. Oil use must be confined to a few irreplaceable uses where alternatives are prohibitively expensive.

But there is not time to wait for this to happen by market forces. Governments must act globally in a concerted way to accelerate the phasing out of all fossil fuels:

- Limit oil production thereby increasing the oil price.
- Implement a carbon price* and penalize imports from countries that don't have a C price.
- Limit oil consumption. **Rationing of gasoline and diesel for personal use** would be a fair and equitable measure, putting the onus on consumers as to how they use limited allocations.

A low carbon price of $20/ tCO2e would suffice speed up the transition to 100% renewable electricity rapidly, thus providing a secure alternative to oil. But this price alone would not be enough to stimulate a rapid switch from fossil fuels. Voters must elect governments that will implement policies for renewable electric and hydrogen powered transport and replacing methane producing ruminant animal farming with clean low impact farming practices.

Reducing our carbon emissions: Carbon footprint checklist

If we are serious about reducing greenhouse gas (GHG) emissions, we need to start with our own household or small business activities/ items that are most emissions-intensive. The check list below summarizes the 6 major areas of domestic energy consumption and carbon emissions. The aim is to start a personal 'carbon footprint scorecard' of how many tonnes of carbon we emit per year (t CO2e/ yr.) We can then find ways to shrink our carbon footprint. This can easily be done with GHG-Energy Calc as the output screen is the scorecard. First we need to ask ourselves 6 questions:

1. How often do we take flights or cruises?

If so, air travel will produce more GHG emissions than anything else you do. For example an economy return trip by jet aircraft to Europe from Sydney for one person results in about 3.4 t CO2e (10.2 t if traveling first class). Ocean cruise holidays are the most carbon emission intensive way to travel. Using a luxury suite trebles emissions; 10,000 km in one of these emits 6 t of CO2e.

Transport is now the largest single source of greenhouse gas emissions in the US. We need to change our travel habits. But in addition to this, governments need to legislate for cleaner transport. We must vote for politicians who will support legislation to reduce carbon emissions, for example:

- Economy-wide price on carbon.
- Increase fuel taxes and road user charges.
- Improve bus, train and bicycle facilities.
- Vehicle fuel efficiency standards.
- Install EV charging networks
- 'Walkable cities'
- Emission reduction programs for industry

The real cost of air travel is not paid by travelers today. A pre-WW II international agreement means there is virtually no tax on aviation fuels and they are exempt from carbon taxes. Flying is therefore cheaper than it should be.

2. Do we use our cars efficiently?

Traveling in large vehicles that are not utilized to capacity is the most polluting activity that we do. If the household uses two mid-sized cars for regular driver only commuting, these can account for up to 10 t of greenhouse gases per year and car transport will be the greatest source of CO2 emissions. Travelling the average distance of 16,600 km per year alone in a large car will add 6 t CO_2e per year to your carbon footprint (4.8 t from fuel burned and 1.2t embodied). Travelling the same distance with 4 people in the car, CO2e emitted falls to 1.6 t per person and by bus, about 1.0 t.

Fuel excise is charged on gasoline and diesel to fund roads and road trauma. The rate is 42 c/L in Australia, which is low compared to 60–95c/ L in other OECD nations *(Australian Institute of Petroleum)*. There is a compelling case that fuel taxes should be increased to cover a carbon price and the cost of respiratory illness and deaths caused by air pollution from vehicle exhausts. Also, big road users should pay proportionally towards their pollution impacts. This could be achieved by road user charges and/ or including license and insurance in the cost of fuel.

3. Are our water and space heating appliances efficient?

In Australia, China, India, Poland and some US states, 70% or more of electricity still comes from coal fired power stations. These are the most carbon polluting way to generate electricity. SA has achieved 50% renewable electricity and no coal generation.

Space and water heating account for at least 50% of home energy use and emissions. Heating the home with electric heat pumps (reverse cycle air conditioners) produces only 1/3rd as much CO2e as oil burning or electric heat element equivalents. Solar appliances produce even less. CO2 emissions from home energy can be cut by up to 50% by:

- Installing rooftop solar PV and solar or heat pump hot water heating.
- Running pool pumps, electric HW heating and washing machines in the middle of the day when PV generation is highest.
- Replacing oil heating systems with electric heat pumps or wood pellet heaters.
- Insulating and draught proofing our homes
- Using air conditioning efficiently.

4. Are our house, cars and things bigger than they need to be?

Energy is used in the production and manufacture of everything we own. This energy, termed the embodied energy, varies according to the type and weight of materials, and also the manufacturing processes used. The resulting embodied CO2e can be apportioned over the life of the product, e.g.:

- A typical large car accounts for 1.1 t CO2e / year in embodied carbon, assuming a 15 year life. This is about 1/4 of the emissions from fuel used by that vehicle.
- An 'average sized' double brick and tile house of 185 sq. metres with typical furnishings, plus the household's possessions for 4 people accounts for about 4.3 t of embodied CO2e/ year.

Down-sizing house and cars to half the sizes stated above would reduce embodied CO2e by over 2 t per year and fuel and electricity emissions by 5 t.

5. Do we consume much meat, dairy, and highly processed food?

If so, the emissions score for food is likely to be about 3 t / year / person in the household. This can easily be halved by not consuming red meats, and minimizing consumption of highly processed, packaged and imported foods.

Replace some or all meats, diary and butter with nut and grain based foods (breads, pastas and pulses such as soy and lentils) and vegetable oils. To reduce packaging/ container waste, consume home cooked food and home-brewed drinks. Purchase products with minimal packaging. These changes will also make for healthier eating.

6. How much is thrown in the bin?

Embodied fossil fuel energy and methane produced by the waste typical households throw out to landfill accounts for up to 1 t CO2e per person per year. By reducing, reusing, recycling and composting this figure can be reduced to near zero. Governments need to legislate for mandatory recycling, waste to energy and container deposit schemes.

How to reduce our carbon emissions

• Air and sea travel

Greenhouse gas emissions for jet aircraft travel are similar to one person traveling by car. A passenger travelling on a medium – long haul flight uses about 3.5 L of fuel per 100 km, emitting about 12 kg CO2e/ 100 km. These figures are trebled when travelling first class. Embodied CO2e from construction and maintenance of the aircraft are added to this.

It is the huge distances traveled in a short time that makes flying such a carbon intensive activity.

In addition to CO2e, aircraft at high altitudes produce other pollutants that cause additional warming of the atmosphere. Hot jet turbine exhausts emit much high levels of nitrogen oxides (N2O and NO_2) than internal combustion engines. These react to form ozone, a potent but short lived greenhouse gas. Water vapour and a small amount of soot (contrails) are also produced, forming high ice clouds, which also have a warming effect. These pollutants cause short term (several day) radiative forcing equal to about 1.5 – 2 times that of the CO_{2e}. As the degree to which they increase global warming is uncertain, GHG-Energy Calc does not include them and therefore its CO2e estimates from flights underestimate the real global warming effect.

Flying business or first class takes up 2-3 times the space of economy class, thus accounting for 2-3 times the emissions. An 'all economy' configuration can seat up to twice the number of passengers than a 3-class configuration on the same type of aircraft.

Short-haul jet flights produce even more emissions per km than long-haul flights, because much more fuel is consumed on take-off, ascent and landing than is used in level flight. Often, short-haul plane flights are taken as a time saving alternative to bus and train services to the same destination. An economy return flight of 800 km produces about 270 kg CO2e per person, 2 times more than by bus and 3-4 times more than by train and this is not counting the other damaging pollutants produced by aircraft. Is a time saving of several hours really worth the damage to the atmosphere? Sight-seeing can be enjoyed en route and the service usually terminates near the destination, eliminating airport commuting.

Although average per capita fight miles comprise only 5% of an average carbon footprint, for frequent or long distance fliers it is many times more. For example, if a Sydney family of three decides to holiday in England (34,000 km return flight) they will emit 10.2 tCO2e for the flights, which is 30 % of a typical household's carbon footprint. If they all travelled business class that portion would double to 60%.

Ocean cruise liners incur even more carbon emissions than jet aircraft. Budget class cruising emits about 22 kg CO2e per 100 passenger km. (About 10 % is embodied energy of the ship). Luxury suites incur over 3 times this figure. The main reason for the inefficiency of cruise ships is the huge mass – 20 - 60t of ship - needed per passenger. It is best to limit ocean cruising experiences to cross-channel and river ferries and cargo ships that carry freight as well as passengers. *Note: Shipping is efficient for freight and bulk products because only 1-2t of ship is required per ton of freight.*

cool tips

Fly and cruise light

- ***Wherever possible, go by bus or train or well-loaded car instead of flying.***
- ***Travel economy class – business or first class incur 2-3 times the emissions due to greater space taken up. This applies to travel by aircraft, ocean liners and overnight trains.***
- ***Holiday locally; there are many excellent destinations within 800 km of home.***
- ***Take fewer overseas trips, stay longer and have a better holiday. For example, every economy return flight from Sydney to the US or Europe adds 3 - 10 t to your personal emissions score.***
- ***Going overseas once every 10 years and staying 6 months to a year rather than every year and staying 2-3 weeks reduces your flight carbon impact 90%.***
- ***Calculate flight emissions before taking flights. Use GHG-Energy Calc for quick calculation. Pay into a 'Carbon Neutral' program to offset flight emissions.***
- ***Support introduction of a tax on jet fuel. Offset the flights and cruises you do take. Cheap air fares do not begin to cover the real environmental cost of flights.***
- ***Ocean cruises are the most carbon intensive holiday choice. Best to limit nautical travel experiences to cross-channel or river ferries or cabins on cargo ships.***

2. Our Vehicles

Our cars account for about 24% of our carbon footprint. People in modern cities seem to be addicted to car travel. Average car ownership is >800 per 1000 people and most households have two or more cars. Throughout the 20th and 21st centuries cities have developed with the automobile and our cities have been designed around it. Most suburban dwellers now live further than walking distance from shops, services and work and habitually drive to all these places. More than 80% of trips are done by car and average car occupancy is only about 1.5 persons. Although most people in the Western world have grown up with the car and see individual car use as normal, this situation has only existed for about 70 years and is already unsustainable.

Car transport is the largest source of greenhouse gases from US and Australian households. We have to change our energy-hungry, polluting 'car culture'. This can be achieved by increasing our use of the more energy-efficient modes of travel, such as bus, train, bicycle, electric 'micro-vehicles ' and shared car. Electric vehicles have a lower carbon footprint but do nothing for congestion problems. Table 2 lists CO2e emitted per 100 km per passenger from the most efficient commuting options. It shows that we can continue to travel the same distances with only 10–20 % of the GHG emissions by switching from 'driver-only car' to public transport, ride sharing or ultra-light personal transport. Table 3

shows the dollar and GHG emission savings from changing to more efficient transport modes.

The main problem today is the use of cars and SUV's vehicles for transporting one or two people. One person driving alone in a medium to large car, as is usual in the US, Canada, Australia and many parts of Europe today uses 9 to 15 litres of fossil fuel, and emits 24 – 43 kg of greenhouse gases for every 100 km traveled.

To keep the per passenger fuel consumption to a minimum, we need to travel in vehicles loaded to their design capacity (Table 2). Even light cars must carry 3 occupants to be as efficient as a bus; large cars or SUV's need to carry at least six.

As most of us rarely ever do this, it does not make economic or environmental sense to have an SUV for private use. A useful 'rule of thumb' for vehicle efficiency is a maximum of 250 kg of vehicle weight for each passenger. This means changing our attitude to personal transport, using lighter vehicles and sharing them more. Large families can reduce their carbon footprint a lot by having two small cars instead of one SUV.

All buses and trains need to be made lighter, electrified and fitted with regenerative braking. Bus and train fares need to be reduced to encourage more people to use public transport.

Table 2. Guide for efficient occupancy of vehicles

Vehicle	Number of occupants	Vehicle weight (t)	Fuel cons. L/100 km	L / 100 passenger km	kg CO2e/ 100 passenger km
Bus	20	9	40	1.1	5-6
Electric train	300	105	n/a	n/a	3-4
E-bike or mobility scooter	1	.02	n/a	n/a	2
Light car or EV	3	.9	5	1.7	5.2
Large car or med SUV	6	2.4	12	2.0	6
Motor cycle 150cc	1	0.15	2.5	2.5	6.6

Electric bicycles are a transport 'game changer'; With panniers they carry 20 kg of shopping.

E-motorcycles – a fast, fun way to cut commuting emissions by 80% and eliminate parking costs.

cool tips

Better Commuting Habits

- *Take the bus or train –read, chat or sleep on the way and save dollars on parking. Commuting 10,000 km by bus or train instead of driving the car will reduce your annual GHG score by about 2.5t.*
- *Try 'car pooling' or ride sharing instead of driving the car alone. Commuting 10,000 km with four people in the car can save 2 tCO2e and hundreds of dollars on fuel and parking.*
- *Live closer to your place of work. One hour's car commute saved is 5 hours per week spent on recreation or with family and reduces your carbon footprint by > 2 t.*
- *Working from home 1 day a week saves 3000 km - 0.8 tCO2e - on a 60 km driver-only car commute.*
- *Cycle or walk instead of driving to shops or a nearby work place. Adults of average fitness can cycle 10 km or walk 3 km with little or no sweat. Get a good quality bicycle or E-bike and ride it.*
- *Become healthier and fitter while cutting 0.7 t from your carbon footprint by cycling and walking 10 km per day (3,500 km/year). Use bike paths and safe streets; wear a helmet and 'hi-vis' vest for safety.*
- *If you have a large car and must drive alone, changing to a small car, EV or motor scooter will cut fossil fuel consumption by 50% or more.*
- *For large families, owning two small vehicles emits less CO2e than having one large car/ SUV if it is being used mainly with less than 3 passengers.*

Table 3. Dollar and emissions savings from changing to more efficient transport mode (20,000 km)

Change from	Change to	Approx. Dollar savings, for 1 year 20,000 km	CO2e emission savings tCO_2e
Large near new IC car, driver only, cost (including fuel, parking at $18 per day and depreciation) for 20,000 km = $11,000	Bus or train	$9,500	5
	Car with 5 occupants sharing cost	$8,800	4
	Scooter 125 cc	$4,000	4
	Light car, or hybrid driver only	$3,000	2 – 3

Choosing a vehicle

The decision as to what vehicle to buy probably has the biggest effect of all on carbon footprint. A new car will likely last 15-20 years and travel over 200,000 km, emitting 30 – 90 t CO2e before it is scrapped. The most sustainable option is to have no car at all and travel by public transport and electric bicycle or mobility scooter, hiring a car for the few times you may need it to carry passengers or loads.

Remember most trips are with only one or two occupants. If you do buy a car, make a wise choice and buy the smallest lowest emissions model that will satisfy your needs. As a rule of thumb this is what you would use to at least 50% capacity more than 90% of the time. If you already have a large fueled car and need it occasionally to move a large family, it can be left in the garage and only used on those occasions.

Electric vehicles (EV's) are the only type that will enable people to reduce their carbon footprint to sustainable levels. There are 3 types of EV's – PEV, PHEV and hybrid. **Plug-in electric vehicles (PEV's)** are the lowest emitting, most sustainable choice. These are fine for most people, who travel mainly in cities or on main highways where fast chargers are available**.** PEV's are powered entirely by electricity from their storage batteries. They have adequate range (200-500 km) and can be charged at home from a 10 amp socket. CO2 emissions are 15%-90% lower than IC equivalents, depending on the EF of the electricity grid and EV's are quieter and faster accelerating. Purchase price is now little more and energy and maintenance costs are halved (see Figure 4). Bus and taxis fleets are now being electrified, saving millions in running costs.

For those whose mileage is mainly long trips where fast charging facilities are not always available, a **plug-in hybrid EV (PHEV)** may be the best option. **PHEV's** can travel up to 60 km on a battery powered electric motor and have a gasoline engine for where there are no charge points. Fuel consumption is <3 L/100 km.

Hybrids have an efficient gasoline engine assisted by an electric motor in the drive-train powered by a battery charged from regenerative braking. Hybrids cost no more than many conventional cars of the same size and use as little as half as much fuel. Mid-sized Hybrids can be bought for AU$32,000, comfortably seat 5 people with their luggage and use 4.2L/ 100km - half the fuel of the IC engine version of the same model. These are suitable for remote locations or states that still have fossil fueled electricity.

Small gasoline fuel injected 1.0 to 1.3 litre hatchbacks will return less than 5L/100km. At <AU$15000, these are the cheapest compromise for those on a low budget. In 2020, any car using more than 5 L/100 km is substandard in terms of fuel efficiency and emissions and should be avoided.*

Diesel engines should be avoided due to their toxic exhaust emissions. Diesels are designed for heavy load applications, but are not suitable for private vehicles. Diesel is a higher energy fuel than gasoline and the engines are more fuel efficient but CO_2e emissions are similar because diesel has a higher emission factor. **Bio-diesel** incurs about 50% of the GHG emissions of diesel but oilseed production displaces food producing land and forests. Carcinogenic particulates (PM2.5) from diesel exhausts comprise 70% of the cancer risk from air pollution in California (OEHHA, 2001). **LPG, LNG and CNG engines** emit about 15% less CO2e than the equivalent gasoline vehicles, but higher cost for little reduction in emissions means they are no longer viable for cars. They can be used in trucks and buses, for fuel cost savings on long haul routes or in cities where the cleaner exhaust reduces air pollution.

Electric trucks and buses have much lowerCO2 emissions and toxic exhaust emissions are eliminated. They are now widely used to replace diesels. The slightly higher capital cost is more than offset by the halving of energy and maintenance costs over the life of the vehicle.

What type of vehicle is least polluting?
EV's have by far the lowest carbon footprint, even with fossil fueled electricity generation. As EV's do not produce tail pipe emissions, they greatly reduce air pollution in cities.
When charged from fossil fueled electricity grids such as China and NSW Australia, EV's emit 15-25% less CO2e than equivalent gasoline vehicles. When charged from cleaner electricity grids such as Europe, EV's emit 50- 80% less (Figure 4).

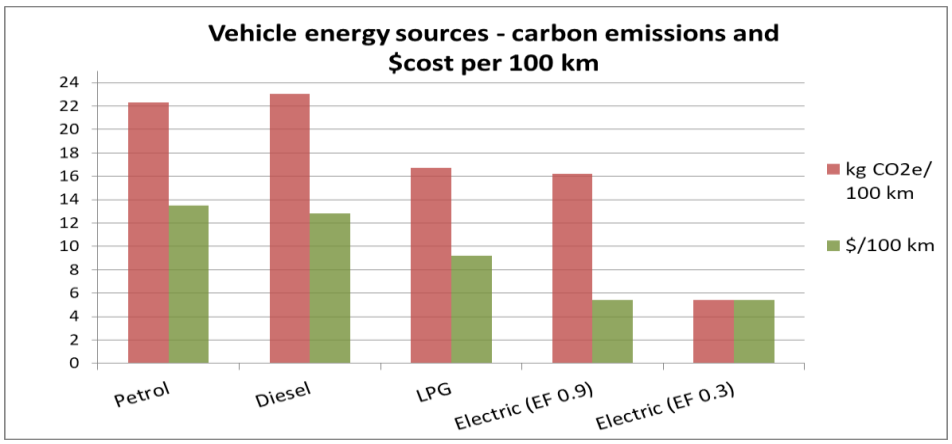
Everyone buying a new car should make it one of the three types of EV described above. All new vehicles will have to be EV's by 2030 for there to be any chance of keeping carbon emissions below the 450 ppm threshold for severe, irreversible warming. The emissions and pollution from IC engine vehicles in particular diesels is becoming so damaging to health that they may be banned in some cities by 2030.

cool tips

Choosing a new vehicle

- ***Go without a car (or second car) if you can. This will not only save you money but also saves the embodied CO2e resulting from manufacturing it –up to 1.2 t per year.***
- ***A vehicle's weight and type of engine are the biggest factor affecting its fuel consumption and carbon emissions. For example typical light car (0.8 tonne) with 1 litre engine – 5 L/ 100 km; typical medium SUV (1.8 tonne) with 2.4 litre engine – 10 L/ 100 km.***
- ***Electric vehicles emit 20% to 80% less CO2e depending on the type (hybrid, PHEV or PEV) and the emission factor of the electricity grid.***
- ***Select a vehicle of a size that you will use to more than 50% full capacity most of the time and choose from the lightest, most fuel efficient models.***
- ***Buy an electric vehicle (EV) if you must have a new car. EV's are the lowest emission and increasingly the most cost efficient option.***
- ***If you are on a budget electric bikes and motorcycles are cheaper and even cleaner options.***
- ***If you need more room or want to carry loads occasionally, hire a large vehicle use a trailer or get things delivered in a hire truck.***
- ***Remember that trains, bicycles, buses and mobility scooters are the least polluting, cheapest, healthiest and most sustainable vehicles. Use these where possible.***

Figure 4. Carbon emitted and fuel cost per 100km for a medium car using different energy sources



**Note: New vehicle fuel consumption labels always underestimate. E.g. a large diesel SUV model claiming 8.5 L/100 km averages 10.5 from drivers' actual figures. Check real fuel consumption at http://www.fuelly.com/*

Embodied CO2e of vehicles

Vehicles are so large these days it's like driving around in a lounge room. Embodied CO2e from manufacture and maintenance of you vehicle adds another 20% to fuel emissions and construction of roads and parking lots still more.

Making a vehicle last longer can reduce embodied CO2e if the vehicle is fuel efficient. However, replacing it with a new one that is even 10% more fuel efficient will reduce the per km GHG emissions by more than would be saved by keeping the old vehicle on the road. New vehicle technologies may use more light-weight alloy and plastic components, which have about 5 times higher EE per kg than steel. However, the reduced weight and improved fuel efficiency more than offset the higher EE. As a general rule, the embodied energy of new cars currently on the market is proportional to the size and weight of the vehicle:

- CO_2e from the manufacture of cars is approximately 6 t CO2e per tonne weight of vehicle and maintenance adds a further 2 tCO2e. (Hawkins, 2012;Chester et al, 2008)
- Embodied CO2e of EVs are about 20% higher than for IC vehicles as a lot of electricity is used in battery manufacture

GHG-Energy Calc annualizes vehicle embodied CO2e over an assumed 15 year lifetime and adds this to operational carbon emissions.
These are only indicative figures. In real-life situations there will be significant variations, depending on such factors as actual age at which the vehicle is scrapped, energy sources, and manufacturing plant efficiency. Accurate comparisons between vehicle makes and models will only be possible if LCA labeling.

cool tips

Using vehicles efficiently

- ***Change to a lighter vehicle or EV. The greater the weight of vehicles you own the greater will be the fuel consumption and the amount of embodied CO2e you are responsible for. By changing from a heavy (1.8t) to a light (0.9t) vehicle or EV, you will save 0.6 t of embodied CO2e in addition to up to 3 t CO2e from fuel combustion per year.***

- ***Your vehicle(s) should be of a size that you will usually use to near full capacity. Plan all trips so that the vehicle is at least 75% fully loaded.***

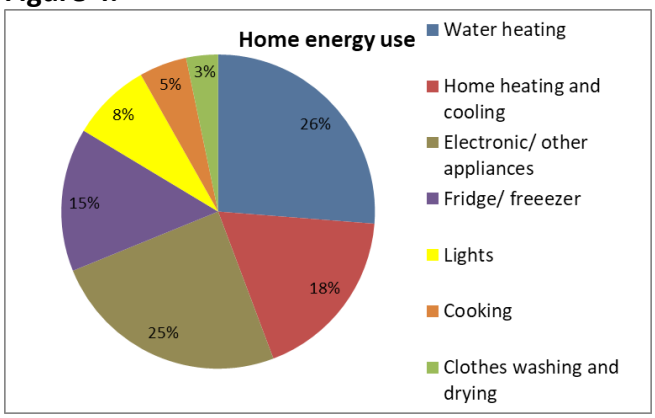
- ***If you need a heavy vehicle or 4WD occasionally, hire one rather and owning it and using it for commuting. Don't keep an old polluting 'fuel guzzler' to save embodied emissions. Replacing it with a newer, lighter, low emissions model (EV is best) will greatly reduce carbon footprint.***

- ***Consider doing without a car. This will cut your transport embodied CO2e by more than 70%. Alternatives are using public transport and having a bicycle or moped. For the occasions that you still need a vehicle, hire one or join a car pool.***

- ***Fit a tow hitch if you want to carry more things occasionally in a small car. Small cars can carry much more than most drivers think they can. A 1.3 litre 5-speed car will easily tow a 400 kg trailer at 90–100 km/ hr in 4th gear without damaging the engine.***

3. Home Energy

Figure 4.



Home energy accounts for about 15% of the average Australian's carbon footprint. On average at least 44% of annual home energy use is in hot water heating and space heating / cooling. In colder southern or alpine areas, space and water heating may be more than 3 times average. In the tropics, air conditioning is by far the largest component of home energy use. The main reason for the high emissions from heating is that many homes still have electric element hot water storage and space heaters. Electricity in China, Australia, India and some US states is still around 60% generated by coal fired power stations. Coal has the highest carbon emissions of any fuel and electricity is only about 30% efficient. More than two thirds of the energy is wasted as heat and transmission losses. Burning cleaner heating fuels such as wood pellets or gas directly in a heaters or HWS is more than 80% efficient.

Electric element heating appliances emit about 3 times more CO2e than equivalent heat pump or gas units. Reverse cycle air conditioners pump heat into the room from outside with about 250-300% efficiency, which offsets any inefficiencies of fossil fueled electricity generation. These are lower emission options than gas except in a few regions with predominantly brown coal fired electricity, which has a very high emission factor. Fans use > 90% less energy than A/C's.

cool tips

Home Energy Savings

- ***Make sure you have an efficient SOLAR, HEAT PUMP OR GAS HOT WATER SYSTEM and WATER SAVER SHOWER HEAD installed. Changing from electric element to SOLAR-GAS can reduce your carbon footprint score by up to 3 t CO2e.***
- ***If you have pool or garden pump, they are big energy users. Set to run for only a few hours a day.***
- ***Install solar PV panels on your roof. Do washing and set electric water heating and pool pumps to run between 9 AM and 3 PM to maximize use of clean solar energy.***

- ***If buying a new heater, air conditioner refrigerator or washing machines make sure it is '5 star' energy rated and no larger than the family needs. These are the most 'energy hungry' appliances.***
- ***Laptops computers with flat screens use much less energy than large desktop computers. Large CR or plasma screens use several times more energy than small/ flat screens. Switch set off at the power point when not in use; they can draw 6 W on standby.***
- ***Change to energy efficient light bulbs. Replacing 10 incandescent or halogen bulbs with ten 6 watt LED's reduces carbon footprint by up to 1.0t. Energy savings cover the cost in 6 months.***

Home Heating and Cooling

First priority –Replace oil fired or electric element heaters *with electric heat pump ('split system' reverse cycle air conditioners) or wood pellet heating systems.* ***This will reduce your heating emissions by 60-80%.***

Set heater thermostats at ***20-22 degrees C*** *and put on more clothes before using the heater. Use an electric blanket (30W) instead of A/C (1000W)*

Large ducted air conditioning units are big inefficient energy users; they can use 3-5 times more energy than all of your other appliances combined. ***Split system or evaporative systems use half as much energy. Fans are the lowest energy cooling option of all, using only about 5-10% of split system A/C's.*** *Only heat or cool the room you are in. Set A/C thermostats at* ***25- 27 degrees C*** *and use fans instead on warm days. Place heaters, A/C outlets or fans as near as possible to the centre of the room.*

By spending less than $2000 to retrofit living rooms, you can save up to 40% on heating bills while keeping the house cooler in summer:

- ***Insulate ceilings, exterior walls and suspended floors.***
- ***Install close-fitting, heavy curtains***
- ***Limit size of most windows; double glaze in extreme climates.***
- ***Fit draft seals to doors.***

These tips can prevent up to 40 % heat loss

Install passive solar in living rooms:

1. *Reduce summer heat gain and winter heat loss.* ***Place large windows on the 'winter sunny side' (south in N hemisphere and north in S hemisphere). Minimize windows on the 'winter shaded' side to minimize heat loss.***
2. *Tiled concrete floors store solar heat coming in from 'sunny side' windows in winter.*
3. ***Properly designed eaves, shutters, verandahs pergolas or shade cloth to*** *shade out the summer (but not winter) sun.*

Hot Water Heating

If you have an electric element storage hot water system, first priority is to replace it with a solar HWS (gas boosted is best), or electric heat pump if you have rooftop PV.

CO2e emitted will be reduced by 60-90%, with energy savings of up to $12 per week.

Showering uses at least half of your hot water. With traditional shower heads, most of the water goes straight down the drain. ***Install a 'water saver' shower head.*** *It will reduce hot water flow from your shower from about 12- 14 L/ min to <7L/ min. This is 50 % less water to heat, which means 50% less carbon emissions. You can adjust the taps and shower head so it warms you just as well.*

Look for the energy star rating sticker on new hot water systems and select a system with four or more stars.

Electric heat pump HWS's are up to 3 times as efficient as the common heat element units and are a cost efficient clean option with low emission electricity (e.g. rooftop PV). But with coal fired electricity (as in Figure 7) emissions are higher than solar with gas or wood boost.

Solid wood heaters can cause severe smoke and methane pollution. They are not recommended in urban areas. Boosting from an ASA standard wood or pellet heater is an option. But always use dry wood keep the fire burning brightly and keep the air supply open. Pellet heaters are the cleanest solid fuel option.

4. Food, groceries and water

CO2e embodied in food, groceries and water accounts for about 22% of an average family's carbon footprint. Across all foods embodied CO2e is emitted from the fuels used to provide energy used for production of fertilizers, on-farm cultivation and irrigation, processing, packaging and transport. About 16,000 MJ of energy is used to produce, store, process, package and transport the food, groceries and water that an average person consumes in a year. In Western countries, nearly all of this energy is sourced from fossil fuels – petroleum, coal fired electricity and natural gas.

It takes many times more energy to produce meats and processed foods than the energy value of the food itself. For example meats, dairy and highly processed foods have embodied energy: nutritional energy ratios of 4 to 8:1; i.e. it takes 4 to 8 times more energy to produce these foods than is contained in the food. In contrast, the ratio is less than 1:1 for breads, cooking oils, fresh potatoes, nuts and flour, which contain more energy that it takes to produce them. For pastas, nuts and fresh fruit/ veg the ratio is about 1.5:1

Bottled drinks such as soft drinks, wine, beer and 'spring water' generally have embodied energy: nutritional energy ratios of more than 6. In the case of wine and beer the bottle can incur as more embodied CO2e than the beer or wine in it. Containers and packaging are also the major cause of the expensive waste disposal problems facing cities today. Cutting down consumption of containerized drinks and highly packaged foods is one of the most beneficial steps one can take both for health and environmental reasons.

Some foods, in particular red meats are much more carbon intensive than others (Figure 5).

Due to the methane emitted from the digestive tracts of ruminant farm animals, the production of red meats, cheeses and butter emits 20 - 30 times more CO2e than minimally processed grains, pasta, breads and fresh vegetables, which ironically are generally higher is essential nutrients.

Rice incurs the highest carbon emissions of any grain (but still many times less than meats) because rice paddy emits methane. It also uses a lot of water, so it is better to buy 'rain fed' rice that is not flooded rather than rice grown under flood irrigation.

An average person's annual food consumption accounts for about 3t of CO2e per year if they regularly eat red meat, 2t if they eat white meat but no red meat and 1t if they are vegetarian.

Changing from a diet high in red meats and highly processed/ packaged foods to a fresh food, mainly vegetarian diet delivers positive results:

- Much better nutritional value for money
- More than 50% less carbon emissions
- Greatly reduced 'environmental footprint'
- Greatly reduced 'land use footprint'
- Reduced manure pollution of waterways
- Reduced packaging waste.

Water supply emits CO2e from the operations, mainly pumping and desalination, and also embodied in the infrastructure. Reducing water use has a minor but significant effect on our carbon footprint. More importantly, it also shrinks our 'water use footprint'. In a drought prone country like Australia, water supply infrastructure is expensive and has high environmental impacts. Dams flood valuable native forest and agricultural land and bores deplete scarce groundwater. Both can reduce or degrade the ecosystem services provided by nature.

cool tips

Climate Friendly Food Shopping

- *A vegetarian or vegan diet is most climate friendly and sustainable; saves a family of four 6 t CO2e and $5,000 per year. But if you don't want to give up meat here are some suggestions:*
  - *Replace red meats and some cheese and butter with nuts, eggs and oils. Changing from a diet heavy in red meats and processed packaged foods to one of fresh local vegetables, dried nuts and grains reduces carbon footprint by 1.6t per person.*
  - *Replace 3 kg of red meat per week with 1 kg each of chicken, fish and lentils. This will reduce your carbon footprint by 2.3 CO2e. Canned or local wild caught sardines, salmon or tuna has a lower carbon footprint than frozen imported farmed fish.*
  - *Think of red meats as luxury foods, to be eaten as garnishes several times per year.*
  - *Reduce servings of meat from 200 to 100g and add 100 g of cooked lentils, tofu, textured vegetable protein (TVP) or chick peas. Tastes the same and climate friendly!*
- *Reduce consumption of bottled drinks. Make coffee, tea, juices, wine and beers at home. Drink tap water and take a drink flask with you instead. Replacing 14 litres per week of bottled drinks with home brewed drinks will cut the household's carbon footprint by 1.3 t or more.*
- *Use fresh, minimally packaged foods, rather than frozen or canned. Best to eat raw fresh fruits and vegetables. Or make juice drinks at home; it takes a few minutes to make a litre of fresh juice. Growing 500 kg of fruit or veg in your home garden saves 0.4 t CO2e.*
- *Reduce 'food miles'. Purchase local in preference to imported. Transporting food long distances incurs significant carbon emissions. In particular air freighted foods; avoid these.*

Figure 5. Carbon emissions (kg CO2e/ kg) from production, packaging and transport of foods

Figure 6 is an example of dollar and CO2e savings that could be made by a family of four by changing from a diet high in animal products and processed packaged items to one high in fresh local vegetable and grain based products. (Rose, 2007; Eckard, 2007; Carlsson-Kanyama, 2002; AGO, 1999)

Figure 6.

Potential Emissions and Dollar Savings From Food Purchases

Typical Australian Family of 4

** CO2e is all greenhouse emissions from production and manufacture, including CO2 from fossil fuel energy inputs, methane and nitrous oxides from agriculture*

Replace 1 kg or 1 L of	$/kg or L	Est. CO2e* /kg	with 1 kg or 1L of	$/kg or L	Est CO2e* / kg	Typical kg or L replaced weekly, family of 4	saving per week (kg CO2eq)	$ saving / week	$ saving / year
COOL/ JUICE DRINKS (can/bot)	2	1.5	CUPS CORDIAL/ TEA/ COFFEE	0.35	0.3	7	8.4	$12	$601
LAMB/ BEEF	15	14	BEANS, PASTA & sauce	5	3	3	33.0	$30	$1,560
BEEF	20	20	NUTS	12	3	1	17.0	$8	$416
BEEF	25	20	CHICKEN	8	4	2	32.0	$34	$1,768
MILKS interstate UHV	2.2	2	fresh local or soy milk	2	1.2	10	8.0	$2	$104
BUTTER	7	13	OLIVE OIL	12	4	0.5	4.5	-$3	-$130
CHEESE	10	13	NUTS	10	3	0.5	5.0	$0	$0
BEER OR WINE (bot/can/ctn)	3	2.5	HOME BREW BEER OR WINE	0.5	0.8	3	5.1	$8	$390
CANNED FRUIT/VEG	3	1.7	HOME COOKED FRESH/DRIED	2	0.8	2	1.8	$2	$104
CANNED BEANS/PASTA	3	2.1	HOME COOKED DRIED EQUIVALENT	1.5	1	2	2.2	$3	$156
BREAKFAST CEREAL (WHOLE GRAIN)	3.1	3.1	OAT/GRAIN PORRIDGE	2	1	0.5	1.1	$1	$29
BREAKFAST CEREAL (PROC.)	3.9	3.5	MUESLI	3	1.4	1	2.1	$1	$47
FROZEN VEG	7	1.6	FRESH VEG	5	0.6	3	3.0	$6	$312

35.5

TOTAL SAVING PER WEEK	123.2	$103
	kg CO2e	dollars

TOTAL SAVING PER YEAR	6.4	$5,356
	t CO2e	dollars

5. Waste

Municipal Solid Waste (MSW) comprises mainly food scraps, packaging, containers, and discarded consumable items such as newspapers and magazines. Australians on average discard 71 kg of plastic and 184 kg of paper products each year plus about 200 kg of food scraps into kerb-side collection bins *(Waste Wise WA, 2002)*. In addition to this are 100's of kilograms of cheap poor quality plastic and melamine furniture and toys. Waste contributes to GHG emissions in 2 ways:

1. Embodied CO2e from fossil fuel used to make the discarded materials (excluding food which is all accounted for in the food section). This accounts for more than 80% of the total greenhouse gases from waste.
2. Methane generation from anaerobic decomposition of organics (food, paper, cardboard and garden waste) in landfill.

Woody garden waste is not included in GHG-Calc as it is essentially a non-manufactured, renewable product and the fossil fuel energy used to dispose of it would be negligible compared to the other waste streams. It is also assumed that very little garden waste is buried in landfill and that no methane is generated from it, as most municipal councils collect and treat it separately mulching, composting or in 'waste to energy' plants.

It is best to **reduce and re-use, then finally re-cycle** the remaining waste. Recycled metal, plastic and paper materials incur significantly less embodied energy and CO2e than virgin materials (Table 5). Recycling saves an estimated 10% of embodied CO2e.

Table 4. Embodied energy and emissions per kg of landfill and recyclable waste (GHG-Energy Calc)

	Embodied energy (kWh/ kg waste)	Embodied plus methane (kgCO2e/ kg waste)	Methane removed by composting food (kgCO2e/ kg waste)
Landfill bin	3.80	1.47	-0.13
Recyclables bin	6.57	1.40	0
Garden organics food bin (if applicable)	0	0	0

Table 5. Embodied Energy of Virgin vs. Recycled Materials. *Sources: Alcorn, 1998; Gregory et al, 1997*

Material	Virgin MJ/kg	Recycled MJ/kg
Aluminium	196	27
Polyethylene	98	56
PVC	65	29
Steel	40	18
Glass	30	13
Nylon(carpet)	120	32

The energy saved is to some extent offset by the energy required to collect and sort the recyclables but there is still a net saving. Other benefits of reducing landfill are:
Less methane from organic waste
Less impact on the environment
Reduced dollar and land costs of landfill.

Methane emitted from landfill counts as GHG because it is produced from a man-made source – anaerobic decomposition in landfill. It would not have been produced if the organic materials were decomposed or burned aerobically. Disposal of organic wastes by high temperature incineration or aerobic composting produces carbon dioxide, but it does not count as greenhouse gas emissions as it is not from fossil sources. The CO2 taken up by the plants from which the organic materials are made is cycled back into the atmosphere, producing negligible net carbon emissions. Although the energy contained in the materials is wasted unless it is used as a source of heating energy, high temperature incineration of most wood and paper is preferable to disposal in landfill. Exceptions are CCA treated pine, particle board and plastic wastes. Burning these materials is illegal as toxic gases are emitted.

Wasting water not only wastes a precious resource, it also wastes energy. Pumping and desalinating scheme water accounts for 2% of average carbon footprint. In some cities such as Perth Western Australia half of it can come from desalinated sea water, which adds a lot to the already considerable amount of energy used to extract and pump water.

cool tips

The 3 R's of Waste

Reduce, re-use and recycle what is left.

1. ***Don't buy cheap things that you will throw away in a year or two. Quality furniture will last several decades. Kids will have more fun making things than having mountains of cheap toys.***
2. ***Substitute home brewed drinks such as tea, coffee, and cordial for drinks bought in cans and bottles. Making disposable bottles and transporting water uses a lot of that emits a lot of CO2e. Why pay for drinks that are 95% water when you can get it free straight from the tap? Look for fresh minimally packaged alternatives to bottled juices and soft drinks, such as fresh fruit and veg. Buy food from fresh and bulk food markets and refill your own containers.***
3. ***If you have to buy food or drink in containers, choose containers that have less embodied CO2e. In order from lowest to highest: Wet proof cardboard cartons< UHT 'tetrapak' < plastics <aluminium or steel < glass.***
4. ***Compost food scraps. This reduces emission of methane (a potent greenhouse gas) from landfill and enriches your garden soil.***
5. ***Buy fewer newspapers and magazines and refuse advertising 'junk mail'. Over 30% of municipal waste is paper and cardboard. Follow the news on TV, radio or internet instead.***
6. ***Conserve water. Gardens, swimming pools, showering and washing and are the biggest users. Install a low volume shower head, use a front-loader washing machine. Replace lawn with native species, mulch gardens, replace sprinklers with drippers, cover pools or remove them.***

6. Embodied Emissions of Goods

Embodied energy is the energy used to produce the raw materials, process, manufacture, package, transport, retail and maintain all of the goods we acquire or consume.

Annualized embodied energy and CO2e of house contents and possessions are generally at least as much as those from the house itself. This is because houses have a lifetime of 60 years or more whereas possessions such as clothes and appliances have a life of 4 – 20 years. Also, metals, plastics and textiles have much higher embodied CO2e per kilogram than building materials.

Most embodied energy is sourced from fossil fuels in three main ways:

1. Use of fossil fuels as material feed-stocks, e.g. coal is the main feedstock for making plastics and steel.
2. As direct energy sources, e.g. coal and gas for heat; diesel for transport.
3. To generate the electricity used by factories. Coal and natural gas are still the main fuels used in power stations. E.g. coal generates about 70% of the electricity used in China and Australia.

The embodied fossil fuel energy results in emissions of gaseous pollutants. Greenhouse gases – mainly carbon dioxide and smaller amounts of methane, carbon monoxide, nitric oxide and fluorocarbons – comprise the major, though invisible part of these carbon emissions. Other pollutants, such as sulphur and particulate emissions are visible as smoke.

Embodied energy and CO2e have been calculated for some products by a process termed Life Cycle Analysis (LCA). There is considerable variation between different brands of a product and between factories and production locations. Some factors that influence embodied energy and carbon are:

- Energy mix used in production
- Efficiency of production technology
- Transport distance.

Indicative embodied energy and carbon can be estimated for foods and goods, so long as qualifications are given as to the production location, scale of production and the variation that can be expected for that product. For example, the embodied energy of bread made in Australia can be between 6 and 10 MJ per kg. By comparison, the embodied energy of cheese can be between 40 and 100 MJ per kg, most of which is from the production of the 10 L of milk required for every kg of cheese. Although there is a large range for each product, we can say that the embodied energy of cheeses will always be at least five times (and can be up to 15 times) that of breads. *Note: CO2e is even higher as methane is emitted by the digestive process of cattle.*

A compulsory system of Life Cycle Analysis (LCA) labeling is needed to show purchasers the carbon footprint incurred in the production, manufacture, transport and disposal of products. It could also show toxic emissions, water use and water pollutants, enabling them to assess its environmental impacts. Another benefit is that it would motivate manufacturers to provide 'eco-friendly' products. A compulsory standardized 5 star labeling system is already used successfully to show buyers the energy efficiency of new appliances. A similar 'symbol and colour coded scorecard' system could be applied to LCA labeling.

cool tips

Low Carbon Stuff

- ***Test your appliances with an energy meter. Old inefficient appliances in particular heaters, HWS, fridges and air conditioners, are best replaced with new 5+ star energy-rated models; this can more than halve operating energy and emissions of these high energy use appliances.***

- ***Be sure that your needs justify purchasing a new item. It is best to borrow or hire large items such as boats or caravans instead of owning one that's rarely used. Or recondition a used model to make it last longer.***

- ***Purchase quality items, which will last many years. E.g. solid wood furniture will last several decades. It has less embodied CO2e than cheap melamine and plastic, which may not even be recyclable and will likely end up in landfill in a few years.***

- ***If an item appliance is doing the job as efficiently as a new one, consider reconditioning or repairing it instead of scrapping it.***

- ***Prolonging the useful life of an item by buying it second hand, for example clothes and furniture, is a very effective way of reducing embodied emissions and saving money.***

- ***Choose durable brands and materials when buying clothing and shoes. Quality items can last up to 3 times longer and will be worn more. Buy clothing at recycling boutiques.***

- ***Ensure that items you no longer need are re-used; pass them on to those who need them or to second hand shops.***

- ***Use recycled materials where possible. Recycled materials have much less embodied energy than virgin materials.***

- ***Hire rather than own large items that are not used much such as cars or boats***

- ***When finally discarding an item, make sure it goes to a recycling bin or depot. Recycled materials save 10 -75% the CO2e emitted from producing virgin materials. For example, savings of 10- 15% (steel, paper and cardboard), 50-60% (glass) up to 75% for aluminium.***

- ***Ask politicians, producers and manufacturers to:***
  - ***Provide embodied CO2e on product labels***
  - ***Legislate to maximize recycling and 'waste to energy' and minimize landfill***

- *Note: The embodied energy of an item depends on its weight and the materials, processes and energy sources used to manufacture it. Embodied energy per tonne of aluminium and non-ferrous metals> plastics> iron and mild steel> glass> paper> brick and concrete. But, for example some aluminium items have less embodied energy than steel because of lighter weight.*

7. Carbon Footprint of Housing

Choice of house has a major impact on carbon footprint because the size and design of it influences heating and cooling energy used over its entire lifetime (60 or more years).

Added to this are the energy and carbon emissions embodied in the house, which depends on the size, type of construction and the life of the building. In general, lighter weight framed buildings incur less embodied CO_2e than heavy concrete and masonry. Double brick / concrete buildings generally incur about 50% more embodied CO_2e emissions than an all timber houses (see Table 6 below).

The lifetime of a house is also a major factor in determining its annualized embodied CO_2e. For example a brick house 100 years old incurs less carbon emissions than a framed house that was demolished at 40 years of age.

Table 6. Embodied CO_2e of housing *(Source: Rose, 2009)*

Construction type	Carbon emissions per sq. metre of floor area (kg CO_2e/ year over 60 year lifetime)
Timber frame, cladding, and floor, on stumps, tile roof	5.9
Steel frame and roof, fibro-cement clad, concrete slab	7.5
Timber frame, brick veneer, tile roof concrete slab	7.7
Double clay brick, all steel roof concrete slab	9.0

cool tips

Carbon Efficient Housing

- ***Is your house used to its full capacity? The greatest energy inefficiency in housing is under-utilization of space. A large home with few occupants means that each person uses more heating/ cooling energy and incurs more embodied energy. Optimal space is 30- 40 sq. metres per occupant.***
- ***If you are a small family with a large house, consider moving into a smaller home or unit, close to work and shops, and renting out the large home to a bigger family.***
- ***Renovate an old durable home rather than demolishing and building new. Old, well-built walls and foundations can last 100's of years. Re-using these will save 20 -40 t of embodied CO_2e.***
- ***When building a new home or extension:***
  - ***Ensure that walls and ceiling are fully insulated during construction. It costs less than retrofitting and will save thousands of dollars in energy bills.***
  - ***Choose light-weight, durable, strong components such as timber or light galvanized steel frames and fibro-cement or colour-bond cladding where possible.***
  - ***Limit size of windows and/or consider using high performance glass and or double glazing.***
  - ***Have the new home 'passive solar' designed, with all west facing windows shaded***
  - ***A home of energy efficient passive solar design built of light – weight strong insulating materials, can save over 50% on typical energy use over the lifetime of the house.*** https://etoolglobal.com/
- ***Swimming pools and air conditioners use a lot of energy – avoid having them or minimize size.***
- ***Choose split system or evaporative A/C systems- they use < half of the energy of ducted systems.***

Offset your remaining CO2e emissions

Joining a 'carbon neutral' (CN) program is a way of offsetting some or all of your carbon footprint. The CN organization calculates how many trees need to be planted to offset your emissions and you pay accordingly. Permanent tree plantations or woodlots are planted, to fix the CO_2 from fossil fuel energy consumption back into wood, root mass and soil carbon produced by leaf litter.

It must be stressed that 'carbon offsetting' is not a 'stand alone' solution to the problem of increasing atmospheric CO_2 levels. For example, if everyone in Western Australia was to have trees planted to neutralize their emissions, the 5 million hectares that could be planted would be all under trees in about 10 years.

Cutting down on emission intensive activities and choosing cleaner technologies must be the first priorities. Tree planting can 'buy some time' while the world reduces its rate of carbon emissions. Sites planted for carbon offsets must remain under trees for perpetuity. It's acceptable if the trees are cut down for timber but they must be re-established. In that way, the amount of wood growing on a site can vary but an average amount of CO_2 fixed in wood, roots and soil on that site can be estimated. If a site is cleared, the fixed CO_2 is released into the atmosphere and the carbon sequestration is negated.

Carbon Neutral (CN) is a Western Australian based program linked to the Men of the Trees organization. After calculating household emissions using *GHG-Energy Calc* you can pay CN online to offset your emissions by planting trees.

CN tree plantings are highly commended for many additional environmental and economic benefits to current and future generations. Re-establishing woodlots and tree belts on agricultural land that has been over-cleared is urgently needed for:

- Mitigating salinity.
- Providing wood products.
- Providing biomass products e.g. fuel for power, wood pellets and essential oils.
- Wildlife habitat and biodiversity.
- Reducing soil erosion.
- Increasing soil carbon improving soil quality.

cool tips

Tree Planting to Take up CO2

- ***Offsetting your carbon footprint by planting trees is not a solution to global warming; the only solution is to reduce GHG emissions. However, it does 'buy some time' by compensating for carbon emitted by fixing carbon in permanent woodlots.***
- ***First minimize household carbon footprint and then 'carbon neutralize' the remainder***
- ***Join a Carbon Neutral Program. For a cost of about $20 per t CO2e a household's CO2e can be offset or neutralized. The website for Carbon Neutral Australia is: http://www.carbonneutral.com.au and there are many other carbon offset programs world-wide.***
- ***Plant trees on your own land or as a volunteer for a tree planting group.***

Calculate your CO2 emissions and Energy Use

GHG-Energy Calc is a user-friendly calculator, easily downloaded from https://cleanenergymodelling.com.au/ghg-energy-calc/

It is two calculators in one; you only have to type in consumption figures once. Clicking a button near the top right hand corner of the screen switches between energy and emissions results. It gives instant results for 7 categories of consumption on the one screen: air and sea travel, private vehicles, public transport, electricity, other fuels and food/groceries and housing/possessions. Results are shown in kWh of energy per year, t CO2e per year and percentages in each category. Annual fuel cost is also calculated.

How *GHG-Energy Calc* works

The Calculator works on 4 simple principles: Energy is expressed as kWh per unit of electricity or kWh / kg or L of fuel.

1. Every energy source has a greenhouse gas emission factor, which can be expressed as kg CO_2e (carbon dioxide equivalents) per unit of electricity or per kg or L of fuel. The factors are derived reputable sources such as Australian Department of Climate Change Factors and Methods workbook.
2. Every consumer product – food, goods, vehicles, housing and other possessions – incurs embodied energy and carbon emissions from its production. These are expressed as kWh of energy and kg of CO_2e respectively, per unit weight or volume. Even public transport can be attributed an energy intensity in kWh/ passenger km and emission intensity in kg CO_2e/passenger km.
3. GHG-Energy Calc calculates energy and CO2e emissions by multiplying the consumption data entered by the user by the corresponding energy and emissions factors.

Details and information sources are explained in Rose, 2020. *GHG-Energy Calc7 Technical Report*, which can be downloaded from the website.

cool tips

Know your Carbon Footprint

- ***You can do a quick self-assessment using GHG-Energy Calc:***
- ***Go to https://cleanenergymodelling.com.au/ghg-energy-calc/***
- ***Click on Greenhouse Calculator and download it. The files are about 600 KB and can be downloaded and extracted in a less than 2 minutes.***
- ***Use GHG-Energy Calc to self-assess your energy and carbon emissions. It only takes 20-30 minutes to fill in energy and consumption data from a household or business. It will instantly show energy and carbon emissions for transport, electricity/gas, food/groceries/water, housing and possessions, all on the one screen.***
- ***Try other iterations to determine how the carbon footprint of the household or business can best be reduced.***

APPENDIX 1

GHG-Energy Calc7

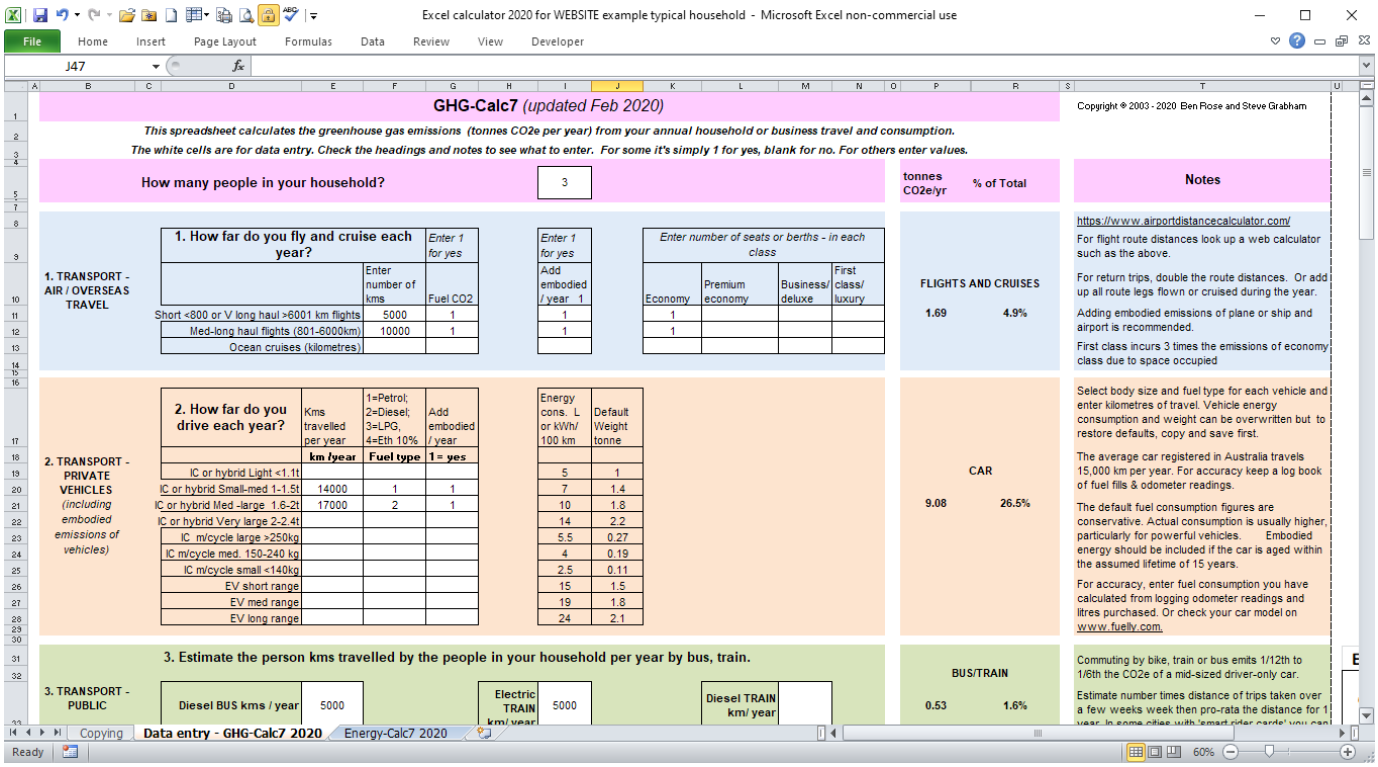
GHG-Energy Calc7 can be downloaded from https://cleanenergymodelling.com.au/ghg-energy-calc/ It is programmed in Excel, which enables the user to see the formulae and constants. There are clear instructions in the headings above the data entry cells and the 'notes' box to the right of each section.

You can 'drill down' into how it works by referring to the details of each section in the Help file https://cleanenergymodelling.com.au/wp-content/uploads/2020/06/GHG-Energy-Calc7-Excel-version-Help-2.pdf.

The Technical Report https://cleanenergymodelling.com.au/wp-content/uploads/2020/06/GHG-Energy-Calc7-Technical-Report-2020-2.pdf outlines the emission factors used in GHG-Energy Calc7 and how they were derived, listing more than 80 reference sources.

It has an advantage over on-line calculators in that you can download as many copies as you like. After entering the household's data, you have a 'carbon and energy footprint' file that that can be printed off in six pages – three for GHG emissions and three for energy. You can do many 'what-if scenarios' and save these too.

Figure A1. *GHG-Energy Calc* screen, showing 'Transport' results for a typical 3 person household.



APPENDIX 2

Table A2. Embodied energy and CO2e emissions per kg of food for 8 categories in GHG-Energy Calc7

Food class	Average energy input MJ/kg	Average energy input kWh/kg	Methane from ruminants (tCO2e/ kg)	N2O from soils, manures (tCO2e/ kg	Emission factor for energy (kgCO2e/ MJ)	CO2e from energy	Estimated total kg CO2e/kg
L1- Fresh / minimally packaged: fruit, vegetables, grains, potatoes, pulses, flour, rolled oats	7.5	2.1	0	0.2	0.08	0.6	0.8
M1 Milks (dairy and soy) in plastic containers	10	2.8	0.7	0.3	0.08	0.8	1.8
M2 – Eggs; canned or frozen fruit/ veg; beer, biscuits, yoghurt, custard, breads, pasta, rice, muesli, soy products; cool drinks/ juices, cakes, toilet paper	17.5	4.9	0	0.1	0.16	2.8	2.9
MH1 - Wines dried fruits/nuts, sugar, breakfast cereals, ice cream, frozen desserts, chocolates, corn/potato chips, margarine, tea/herbs, ground coffee	27	7.5	0	0	0.16	4.32	4.3
MH2 - Chicken, bottled or canned cooking oils, sauces and dressings, jam, honey, syrups, chutneys , canned tuna	37	10.3	0	0.1	0.16	5.92	6.0
H1 - Farmed salmon, soup powders, instant coffee, spirits; soaps and detergent, shampoo, nappies	50	13.9	0	0.1	0.16	8	8.1
H2 - Pork, cheese, butter, cream, milk powders,	62	17.2	3.5	1.4	0.08	4.96	9.9
VH1 - Beef and lamb meat and sausages	95	26.4	10	2.3	0.08	7.6	19.9

APPENDIX 3

Embodied emission factors for goods

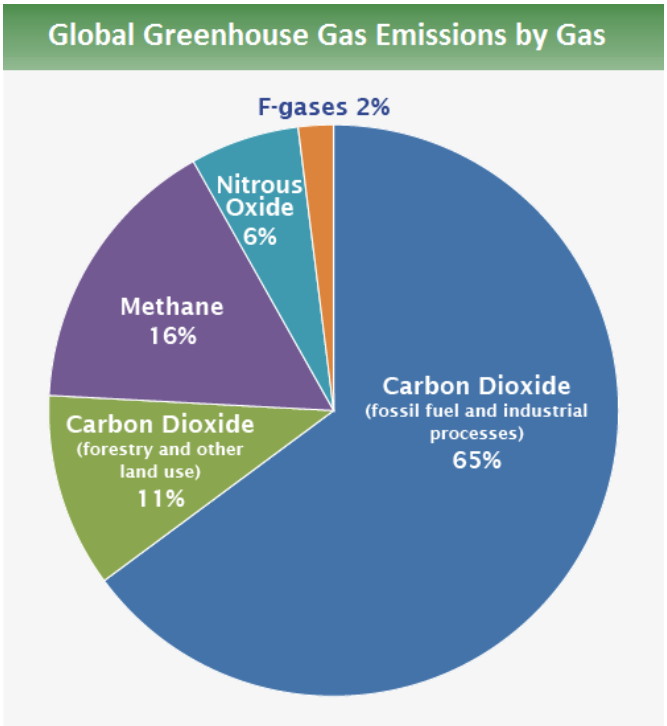
Embodied CO2e for different items are difficult to estimate because production systems are complex and use energy from several sources. Emission factors used in *GHG-Energy Calc7* have been derived assuming different energy mixes for 5 categories of goods and foods:

Cars and appliances Manufactured in Asia						
	Electricity EF (Asia)*	**Oil**	**Gas**	**Coal**	**Total CO2e/MJ**	**Total CO2e/kWh**
EF kgCO2e/MJ	0.183	0.078	0.062	0.093	n/a	
Percent of embodied energy used in production	29%	21%	8%	42%	100%	
kgCO2e per MJ	0.053	0.016	0.005	0.039	0.113	0.408
Buildings in Australia						
	Electricity EF (Australia)	**Oil**	**Gas**	**Coal**	**Total CO2e/MJ**	**Total CO2e/kWh**
EF kgCO2e/MJ	0.222	0.078	0.062	0.093	n/a	
Percent of embodied energy used in production	12%	26%	42%	20%	100%	
kgCO2e per MJ	0.027	0.020	0.026	0.019	0.092	0.330
Foods - Australian processd with high proportion of processing (electicity) inputs						
	Electricity EF (Australia)	**Oil**	**Gas**	**Coal**	**Total**	
EF kgCO2e/MJ	0.222	0.078	0.062	0.093	n/a	
Percent of embodied energy used in production	60%	20%	20%	0%	100%	
kgCO2e per MJ food production energy	0.133	0.016	0.012	0.000	0.161	0.581
Foods - Australian processed foods with moderate proportion of processing (electricity) inputs						
	Electricity EF (Australia)	**Oil**	**Gas**	**Coal**	**Total**	
EF kgCO2e/MJ	0.222	0.078	0.062	0.093	n/a	
Percent of embodied energy used in production	34%	27%	39%	0%	100%	
kgCO2e per MJ food production energy	0.076	0.021	0.024	0.000	0.121	0.435
Foods - Australian grown minimally processed with high proportion of agricultural (fertilizer and fuel) inputs						
	Electricity EF (Australia)	**Oil**	**Gas**		**Total**	
EF kgCO2e/MJ	0.222	0.078	0.062	0.093	n/a	
Percent of embodied energy used in production	8%	45%	45%	0%	98%	
kgCO2e per MJ food production energy	0.018	0.035	0.028	0.000	0.081	0.291

Source: *Rose, 2020*

APPENDIX 4

Figure A4.



Source: US EPA, 2020

Water vapour

Water vapour is the largest contributor to the Earth's greenhouse effect. On average, it probably accounts for about 60% of the warming effect. However, water does not control the Earth's temperature, but is instead controlled by the temperature. This is because the temperature of the surrounding atmosphere limits the maximum amount of water vapour the atmosphere can contain. Even though water is the greatest greenhouse gas, it is relatively short-lived. Water vapour is a '**condensable gas'**, i.e. it condenses to liquid water at temperatures found in Earth's atmosphere. If a volume of air contains its maximum amount of water vapour and the temperature is decreased, some of the water vapour will condense to form liquid water. This is why clouds form as warm air containing water vapour rises and cools at higher altitudes where the water condenses to the tiny droplets that make up clouds. These form raindrops that fall back to earth as rainfall. This is called a positive feedback loop.

The greenhouse effect that has maintained the Earth's temperature at a level warm enough for human civilization to develop over the past several millennia is controlled by non-condensable gases, which can stay in the atmosphere for decades to hundreds of years. These are the 'Kyoto listed greenhouse gases' or 'anthropogenic carbon emissions' shown in Figure A4 above. Emissions from human activities have increased the concentration of these gases in the atmosphere and added small amounts of synthetic 'F-gases' or hydrofluorocarbons. This is the cause of global warming.

Ref: https://www.acs.org/content/acs/en/climatescience/climatesciencenarratives/its-water-vapor-not-the-co2.html

DEFINITIONS

For the purposes of this paper, and in *GHG-Energy Calc*, the terms used have the following definitions:

Carbon emissions
Greenhouse gases, primarily carbon dioxide (CO2) but including many more potent greenhouse gases.

Combustion energy
Combustion energy is the total energy released when a fossil fuel energy source is burned.

CO2e
Carbon dioxide equivalent – unit of measuring carbon emissions, usually expressed as kgCO2e or tCO2e. The global warming potential (GWP) of other greenhouse gases is expressed in units of CO2e, for example the GWP of one kg of N_2O = 300 kgCO2e.

Embodied energy
Embodied energy of an item is defined as the energy used to extract and produce the raw materials, manufacture, package, store and transport and service that good. This energy comes from a variety of sources. Over 90% of embodied energy comes from a mix of fossil fuels – gas, oil and coal.

Embodied CO2e
The sum of the CO2e emissions emitted from embodied energy or a product as defined above, plus other global warming gases such as methane, carbon monoxide, nitrogen oxides and PFC's that may be emitted as a result of any of the production stages. For example methane from ruminant digestion is added to the CO2e emissions from energy used to produce beef, lamb and dairy foods.

Emission factor (EF)
The CO2e emitted per unit of energy, for example kg CO_2/GJ of electricity or quantity of fuel, for example, tCO2e per t of coal. EFs can be categorized as:
Point source – at the point of combustion.
Full fuel cycle – combustion plus CO2e emitted from upstream energy production processes outside the boundary of the point of consumption.

Energy content (of a fuel)
The energy contained by a fuel – that is released when the fuel is burned (oxidised) completely. GHG-Energy Calc uses units of kWh per kg or L.

Fuel energy
Fuel energy is the total energy contained in a fuel, that is released when the fuel is burned (combustion energy), plus the upstream energy used to extract, refine and transport the fuel. Only a fraction of the fuel energy used by vehicles powered by internal combustion engines (reciprocating engines and turbines) is used to move the vehicle - about 20% depending on engine efficiency - the remainder is wasted as heat and friction.

Fuel emissions
Full cycle GHG emissions from energy sourced from fossil fuels.

Full cycle emissions
Full cycle emissions of a pollutant are those emitted from the point source i.e. combustion of a fuel plus the pre-combustion or upstream emissions from the production and transport of the fuel (in the case of fossil fuel carbon emissions, an additional 5-20 %).

Full cycle carbon emission factors
Calculations in *GHG-Energy Calc* and this document use full cycle carbon emission factors, expressed as kgCO2e/ kg of L of fuel or kgCO2e/ kWh of energy.

GHG
Greenhouse gases, which cause global warming

Global warming potential (GWP)
A measure of how much heat a greenhouse gas traps in the atmosphere up to a specific time horizon, relative to carbon dioxide.

Internal combustion (IC) engine
Engine type traditionally used to power most vehicles. Burns fuel (usually gasoline diesel or gas) in combustion chambers to produce power via pistons and a crankshaft.

Kilowatt hour (kWh)
Unit of energy usually used in energy bills. 1 kWh = 3.6 MJ. Equivalent to one kilowatt of power delivered for 1 hour.

LCA
Life-cycle assessment (also known as life-cycle analysis) is a methodology for assessing environmental impacts associated with all the stages of the life-cycle of a commercial product, process, or service. For instance, in the case of a manufactured product, environmental impacts are assessed from raw material extraction and processing (cradle), through the product's manufacture, distribution and use, to the recycling or final disposal of the materials composing it (grave).

Megajoules (MJ)
Unit of energy used in most embodied energy studies

Pre-combustion emissions
Pre-combustion (or upstream) GHG emissions are from the extraction and production of fuels. The figures range from around 10% (CNG) to 22% (diesel) of total fuel carbon emissions.

PV
Rooftop solar photovoltaic panels for self-generation of low carbon electricity

Radiative Forcing
The difference between insolation (sunlight) absorbed by the Earth and energy radiated back to space. Changes to Earth's radiative equilibrium, that cause temperatures to rise or fall over decadal periods, are called climate forcing. Positive radiative forcing means Earth receives more incoming energy from sunlight than it radiates to space.

Tonne
Metric ton (abbreviated as ‘t’)

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