Offsetting Australia's Land Transport Emissions

Tony Richardson
TreeSmart Australia and The Urban Transport Institute, Taggerty, Victoria, Australia

1 Introduction

The topics of Global Warming and Carbon Neutrality have received dramatically increased attention over the past 12 months in Australia. Since the first visit of Al Gore to Australia in October 2006 to promote his film and book "An Inconvenient Truth" (Gore, 2006), a number of events have conspired to raise public awareness of the topics of Global Warming and Carbon Neutrality. The Stern Review (Stern, 2006) that was presented to the British Government highlighted the short-term and long-term consequences of global warming. While there are numerous findings in that substantial volume, the one that appears to have received most attention is the one that concludes that "the benefits of strong, early action on climate change outweigh the costs". A range of public and political events have raised the level of awareness of the extent and consequences of global warning. Many publications (e.g. Flannery, 2005) have expressed in very understandable terms the nature and implications of the problem. The Australian Government awarded Tim Flannery the title of "Australian of the Year", even though he remains publicly critical of the government's policies on global warming. The topics have infiltrated the public mind to such an extent that television programs and series are now based on the topic (e.g. The Carbon Cops).

The transport sector contributes about 15% of Greenhouse Gas emissions in Australia, or around 80 million tonnes of CO_2 per year. While various proposals have been put forward as to how this can be reduced, including travel behaviour change, greater use of public and non-motorised transport, improvements in vehicle technology and fuels and long-term changes in land-use, the fact remains that the total emissions will be reduced only marginally or may even grow with increasing population. If Australia is to reduce greenhouse emissions by 50-60% by 2050 (or 20% by 2020), then alternative means of reducing CO_2 in the atmosphere from the transport sector must be considered. A previous paper (Richardson et al., 2005) have, for example, demonstrated that CO_2 reductions via tree planting may be much more cost effective than CO_2 reductions via travel behavior change programs.

The current paper extends this theme by describing a method of reducing CO_2 emissions from transport based on the offsetting of CO_2 emissions by non-transport means. The paper first outlines an overall framework for considering carbon neutrality in the transport sector (and elsewhere). It then considers the scale of the land transport task in Australia, followed by an estimation of the greenhouse emissions (especially CO_2) generated by that land transport task. The paper then reviews various ways by which those emissions could be offset. Selecting one of those offset methods, biosequestration in forests, it estimates what would be required physically to offset the total land transport emissions each year, and the likely cost of those offsets. The paper then considers various ways in which these costs could be met by society.

2 The MAORI Model of Carbon Neutrality

In seeking to achieve Carbon Neutrality, many individuals and organisations have adopted a range of strategies. For example, the Victorian EPA has recently announced its intention to go Carbon Neutral (www.epa.vic.gov.au/greenhouse/carbon_offsets). In doing so, it has produced a booklet (EPA goes Carbon Neutral) in which they outline a set of Carbon Management Principles, consisting of the following steps:

- Measure
- Set Objectives
- Avoid
- Reduce
- Contain
- Assess
- Offset

In considering the role of offsets, they note that offsets "are an important final component to becoming carbon neutral".

While agreeing with many of the sentiments behind the EPA Carbon Neutral Principles, it is considered that offsets should be used earlier and should be a central component of an overall Carbon Neutral strategy, rather than an afterthought. To this end, TreeSmart Australia works with the MAORI model of Carbon Neutrality, with the following steps:

- **M**easure
- **A**void
- **O**ffset
- **R**educe
- **I**terate

2.1 Measure

The first step in going Carbon Neutral is to ***Measure*** (or at least estimate) the emissions associated with the specific activities. In the context of transport, this is a relatively straight-forward task for land-based transport, since greenhouse emissions (mainly CO_2) are directly related to fuel consumption, and many methods exist for modeling and measuring fuel consumption from land-based transport. For air transport, the position is not quite so clear, since CO_2 is not the only (or the major) greenhouse emission from air transport. At high altitudes, other emissions (even water vapour) are significant contributors to greenhouse emissions, with the result that total greenhouse emissions are about 2-3 times as much as the CO_2 emissions. The UK Commission for Integrated Transport (2003) has recommended a factor of 2.7 be applied to CO_2 emissions to account for the non- CO_2 emissions from air transport, although debate persists as to the best value of this factor to apply.

For land-based transport, however there are numerous sources of information on greenhouse emissions, which are predominantly CO_2, and these will be illustrated later in this paper.

2.2 Avoid

Having identified the greenhouse emissions attributable to an individual, a household or an organization, there may be some activities that result in emissions that are relatively easy to ***Avoid***. These activities are often referred to as "low-hanging fruit", in that they are easy to reach. Examples of such activities in the context of personal travel might include walking to the local shops instead of driving, combining activities on one round-trip rather than making separate trips, inflating tyres to the correct pressure, and using public transport for trips where public transport is a viable alternative.

However, the number of such activities where emissions can easily be Avoided is likely to be relatively few in number, and the total emissions avoidable is likely to be relatively small. If there were large numbers of such activities, then reducing greenhouse emissions would be fairly straight-forward and easily implemented, and we know that is not the case.

2.3 Offset

While other models of Carbon Neutrality (such as the Victorian EPA Principles described above) tend to put offsetting at the end of the chain of activities, the MAORI model puts ***Offsets*** in the centre of activities, for two main reasons.

Firstly, as noted by Stern (2006), there is a need for immediate action with respect to reductions in greenhouse emissions in the atmosphere. While the long-term aim might be to eliminate or change the activities which give rise to the emissions, such changes typically take a considerable period of time (e.g. changing over the fleet to low emission vehicles will take at least 10 years), and we simply can't wait that long to do something about reducing atmospheric CO_2. While waiting for the long-term changes to occur, we need to make immediate reductions in atmospheric CO_2, both for our current activities and also for past activities which have contributed to CO_2 emissions.

Secondly, having offset the emissions that cannot easily be avoided this year provides a metric and an incentive to proceed to the next steps in the MAORI process (reducing and Iterating), as will be described below.

2.4 Reduce

Having avoided the polluting activities that can easily be avoided, and then offset the emissions that cannot easily be avoided this year, the next step is to start to ***Reduce*** the emissions that are not easily avoided and that may take some time to completely remove. This process may take several years to completely implement. Examples of such changes (in a household context) might include reducing the number of vehicles in the household, changing those vehicles to low-emission vehicles, and changing residential location to be in a position to make better use of public transport services. From a policy perspective, the type of changes that will reduce emissions in the future might be investing in public transport infrastructure and services, encouraging higher-density urban development, changing taxation laws to remove incentives for vehicle use, implementing user-pays road-pricing systems, introducing carbon tax policies, etc. None of these changes will occur overnight, and yet we need to make immediate changes in atmospheric CO_2 if we are to stave off the inevitable global warming consequences. This is why Offsets come before Reductions in the MAORI model. We need to take short-term action while we start implementing the long-term actions.

2.5 Iterate

Some Carbon Neutral models imply that the process of going carbon neutral is a once-off process (or at least they don't stress that it is a continuous process). However, for the same reason that Quality Management is a seen as "a process of continuous improvement" (Taormina, 1996), so "going Carbon Neutral" must also be seen as a process of continuous improvement.

So, the final step in the MAORI model is to ***Iterate***. Thus, after Measuring your greenhouse emissions, Avoiding the easily avoided emissions, Offsetting the rest, and then starting to Reduce your emissions in the long-term, the next step is to Iterate the process and go back around and do it all again next year. Next year, your Measurements should show a reduction in emissions (from those that were easily Avoided and those that you have already been able to Reduce). Your early experience may now show a few more emissions that can be easily Avoided. In year 2, you will still need to Offset what you haven't been able to Avoid or Reduce, but the amount of Offsets required in year 2 should be less than what was required in year 1. Indeed, the true test of the success of the MAORI model is that the offsets should reduce year by year until they reach a minimum level. This minimum level will be unlikely to be zero (since some travel and some emissions will almost always be occurring), but the need for offsets should be reduced year by year.

The MAORI model of Carbon Neutrality is applicable at the level of the Individual, the Household, the Organization and the Government. It provides a holistic process which enables short-term and long-term strategies to be implemented, with a view to achieving greenhouse emission reductions of sufficient magnitude, and with sufficient speed, to contain global warming within manageable bounds.

The rest of this paper attempts to address two elements of the MAORI model; Measurement and Offsetting. It does not specifically address Avoiding and Reducing greenhouse gas emitting activities in the transport sector, but does not deny that such activities also need to be undertaken in parallel.

3 Estimating Greenhouse Emissions from Australian Land Transport

The estimation of greenhouse emissions from Australian land-based transport (excluding trains and trams) is based on a threefold process of estimating:

- The size of the fleet of different vehicle types
- The usage of different types of vehicle
- The emissions from different types of vehicle

Data for this analysis is drawn primarily from the ABS Survey of Motor Vehicle Usage 2005 (ABS, 2006a), and the Australian Greenhouse Office Workbook of Factors for Greenhouse Emissions (AGO, 2006)

3.1 The Australian Vehicle Fleet

The number of vehicles of various types in the Australian fleet, by state of registration is shown in Table 1. Of the total 14 million vehicles in Australia, about 30% are registered in NSW and 25% in Victoria with the remaining 45% spread across the other states.

Table 1 The Australian Fleet by Vehicle Type by State

	State of Vehicle Registration								
Vehicle Type	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	TOTAL
Passenger Vehicles	3,357,074	2,980,353	2,063,409	1,178,643	903,868	267,501	187,857	71,801	11,010,506
Motorcycles	114,019	107,613	97,551	53,033	29,625	9,216	7,055	3,436	421,548
Light Commercial Vehicles	575,459	434,258	492,655	242,603	136,213	69,385	18,612	27,084	1,996,269
Rigid Trucks	109,815	88,820	78,244	47,844	26,122	9,669	2,284	4,077	366,875
Articulated Trucks	15,496	21,010	14,968	8,323	6,260	1,486	218	747	68,508
Non-Freight Carrying Trucks	3,966	5,625	3,836	3,559	1,919	1,021	115	261	20,302
Buses	17,534	13,146	14,161	8,194	3,902	1,959	893	2,561	62,350
TOTAL	4,193,363	3,650,825	2,764,824	1,542,199	1,107,909	360,237	217,034	109,967	13,946,358

3.2 Usage of the Australian Vehicle Fleet

Each type of vehicle travels a different number of kilometres per year, and this also varies by state as shown in Table 2. The average passenger vehicle in Australia travels about 14000 km/year, but this varies across the states. In Victoria, the average passenger vehicle only travels about 13,500 km/year, while in Queensland the average passenger vehicle travels over 15,000 km/year. Large articulated trucks travel a far greater distance, with an average of over 90,000 km/year across Australia. Buses also travel a considerable distance, with an average of about 30,000 km/year. Note, however, that this covers all types of buses in Australia, including school buses in urban and rural areas which travel a relatively small distance per year. Urban route buses travel considerably more per year, with the average Melbourne metropolitan route bus travelling about 60,000 km/year.

Table 2 Annual Usage per Vehicle per Annum by Vehicle Type by State

	State of Vehicle Registration								
Vehicle Type	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	TOTAL
Passenger Vehicles	14495	13555	15245	13798	12112	14082	14112	12855	14084
Motorcycles	2956	3726	3711	2960	3105	2930	4961	5239	3390
Light Commercial Vehicles	17986	15866	17475	15189	17106	16387	16065	17132	16914
Rigid Trucks	21791	20041	26353	14505	16155	19340	26708	17905	20912
Articulated Trucks	88539	93717	104423	70648	95847	91521	119266	73628	92091
Non-Freight Carrying Trucks	15381	19378	15120	9834	5732	5877	26087	15326	14137
Buses	30854	30884	29376	27337	33573	21440	33595	25381	29751
TOTAL	15194	14230	16105	14036	13118	14718	14307	14568	14798

Multiplying Table 1 by Table 3 produces the total kilometres travelled by the Australian Fleet, as shown in Table 3. It can be seen that a total of over 200 billion kilometres are travelled by Australian vehicles per year. The majority of these are by passenger vehicles, followed by light commercial vehicles.

Table 3 Total Usage (1000kms) per Annum by Vehicle Type by State

	State of Vehicle Registration								
Vehicle Type	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	TOTAL
Passenger Vehicles	48662	40398	31457	16263	10948	3767	2651	923	155069
Motorcycles	337	401	362	157	92	27	35	18	1429
Light Commercial Vehicles	10350	6890	8609	3685	2330	1137	299	464	33764
Rigid Trucks	2393	1780	2062	694	422	187	61	73	7672
Articulated Trucks	1372	1969	1563	588	600	136	26	55	6309
Non-Freight Carrying Trucks	61	109	58	35	11	6	3	4	287
Buses	541	406	416	224	131	42	30	65	1855
TOTAL	63716	51953	44527	21646	14534	5302	3105	1602	206385

3.3 Greenhouse Emissions from Australian Vehicle Fleet

The kilometres travelled in Table 3 can be converted to litres of fuel consumed, by knowing the average fuel consumption rate for each of the different vehicle types. The SMVU 2005 data (ABS, 2006a) estimates this fuel consumption by type of fuel consumed as shown in Table 4. Note that while the SMVU gives figures for different types of fuel used by each vehicle class, Table 4 assumes a main fuel type for each vehicle class.

Table 4 Fuel Consumption Rates (litres/100 km) by Vehicle Type by Fuel Type

	Predominant Fuel Type	
Vehicle Type	Petrol	Diesel
Passenger Vehicles	11.4	
Motorcycles	5.8	
Light Commercial Vehicles	13.6	
Rigid Trucks		29.2
Articulated Trucks		54.7
Non-Freight Carrying Trucks		24.5
Buses		28.5

The total fuel consumption for each vehicle class can then be estimated by multiplying the distance travelled in Table 3 by the fuel consumption rate in Table 4, to yield the total fuel consumption estimates shown in Table 5. It can be seen that nearly 30 billion litres of fuel are consumed by land transport in Australia each year.

Table 5 Total Fuel Consumption (1000 litres p.a.) by Vehicle Type by State

	State of Vehicle Registration								
Vehicle Type	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	TOTAL
Passenger Vehicles	5547468	4605372	3586098	1853982	1248072	429438	302214	105222	17677866
Motorcycles	19546	23258	20996	9106	5336	1566	2030	1044	82882
Light Commercial Vehicles	1407600	937040	1170824	501160	316880	154632	40664	63104	4591904
Rigid Trucks	698756	519760	602104	202648	123224	54604	17812	21316	2240224
Articulated Trucks	750484	1077043	854961	321636	328200	74392	14222	30085	3451023
Non-Freight Carrying Trucks	14945	26705	14210	8575	2695	1470	735	980	70315
Buses	154185	115710	118560	63840	37335	11970	8550	18525	528675
TOTAL	8592984	7304888	6367753	2960947	2061742	728072	386227	240276	28642889

This fuel consumption can be converted into greenhouse gas emissions by knowing the rate at which fuel consumed is converted into emissions for each type of fuel. These "fuel factors" are provided by the Australian Greenhouse Office in their Workbooks of Factors (AGO, 2006) to be used in estimating greenhouse emissions from a wide array of activities, including fuel use. The fuel factors provided by AGO cover the life-cycle emissions of the fuel, including the emissions produced by combustion of the fuel plus the emissions generated in the production of the fuel. The AGO fuel factors used in this analysis are 2.6kg CO_2-e/litre for petrol and 3.0kg CO_2-e/litre for diesel. Multiplying the fuel consumption in Table 5 by these fuel factors gives the total greenhouse emissions by vehicle type as shown in Table 6. It can be seen that the total emissions are about 80 million tones of CO_2-e per year, with over half coming from passenger vehicles and about 35% coming from trucks and light commercial vehicles.

Table 6 Total Greenhouse Emissions (1000t CO_2-e p.a.) by Vehicle Type by State

	State of Vehicle Registration								
Vehicle Type	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	TOTAL
Passenger Vehicles	14423417	11973967	9323855	4820353	3244987	1116539	785756	273577	45962452
Motorcycles	50820	60471	54590	23676	13874	4072	5278	2714	215493
Light Commercial Vehicles	3659760	2436304	3044142	1303016	823888	402043	105726	164070	11938950
Rigid Trucks	2096268	1559280	1806312	607944	369672	163812	53436	63948	6720672
Articulated Trucks	2251452	3231129	2564883	964908	984600	223176	42666	90255	10353069
Non-Freight Carrying Trucks	44835	80115	42630	25725	8085	4410	2205	2940	210945
Buses	462555	347130	355680	191520	112005	35910	25650	55575	1586025
TOTAL	22989106	19688396	17192092	7937142	5557111	1949962	1020718	653080	76987606

4 An Option for Offsetting Transport Emissions

If it is assumed, as a worst case scenario, that no reductions in kilometres travelled and no improvements in fuel efficiency can be made in the first instance, then a total of about 80 million tonnes of CO_2-e would need to be offset per year to make the land-transport sector "carbon neutral". While such an objective is unrealistic in the short-term, it is informative to see what would be required if this were to be attempted.

While there are many options available for offsetting emissions, it will be assumed in this paper that all the offsetting will be undertaken by way of tree-planting in plantations that are destined for eventual harvesting.

It is recognized that one of the assumptions in the Kyoto Protocol about carbon sequestration in plantations is that if the plantation is harvested at some point in the future, then all the carbon that has been sequestered during the life of the plantation is immediately released back into the atmosphere. The credits that have been accrued during the life of the plantation must then be repaid. While re-planting the trees will allow further sequestration in a new plantation, the sequestration during the initial plantation growth is assumed to be forfeited upon harvesting of that plantation. As a result of this assumption, plantations developed for carbon sequestration purposes have therefore generally been assumed to exist in perpetuity, with no plans for harvesting.

While the Kyoto Protocol regulations for carbon trading assume that all carbon is released back to the environment at the moment of harvesting (primarily because of the current difficulties with auditing the history of the timber once harvesting has taken place, and with allocating the sequestration to the appropriate party in an international context), it is clear that carbon will continue to be sequestered for as long as the timber product is in existence. For example, Jaakko Pöyry Consulting (1999) show that many timber products have extended service life spans from 3 years (for paper and paper products) up to 90 years (for timber used in house construction). Ximenes et al. (2005) and Ximenes et al. (2006) go even further and show that carbon continues to be sequestered in timber products well beyond their service life spans, depending on how the products are finally disposed of at the end of their service life. They conclude that approximately 70% of the carbon from harvested logs in Australia is in equivalent long-term storage in forest products.

Research conducted by TreeSmart Australia (Richardson, 2005b) has also shown that there are several major advantages of harvesting a plantation primarily designed for carbon sequestration.

- By harvesting trees which have reached maturity (and effectively stopped absorbing carbon dioxide) and replacing them with a new planting of rapidly growing younger trees, the total sequestration can be increased over the long-term compared to leaving the original plantation in place;

- By growing the trees for eventual harvesting as sawlogs, a significant proportion of the carbon in the trees can continue to be sequestered in long-lived timber products (while the next plantation of trees starts sequestering more carbon in the new living trees);

- The wood not used for sawlogs (e.g. thinnings, prunings and other harvest and processing residue, which comprises about 70% of the volume of a harvested tree) can be used as a fuel substitute, whereby wood burnt efficiently is substituted for other fossil fuels. While the burning of the wood is carbon neutral (since the growing trees only recently sequestered the carbon that is now being released), the carbon that would have been released from the fossil fuel (that is now not burnt) is now effectively sequestered for a longer period of time. This is especially important in Victoria, where most electricity is generated by the burning of brown coal, which is a particularly significant source of CO_2 emissions. It has been estimated (Ximenes and Davies, 2004), that the release of 1 tonne of CO_2 by the burning of wood for power generation saves about 3.5 tonnes of CO_2 from being released from brown coal for the production of the same amount of electrical power;

- By having another incentive for growing the trees (i.e to harvest them), plantation owners are more likely to take better care of the trees, and undertake regular monitoring, resulting in lower mortality rates and higher growth rates in the trees;

- By having the sequestered carbon in more than one asset (i.e. living trees and timber products) the sequestered carbon is better protected from catastrophic damage by fire and other natural causes, by diversifying the portfolio of sequestration pools;

- The income derived from carbon sequestration is a valuable "off-farm" income source for many farmers;
- The encouragement of harvested eucalypt plantations provides an alternative source of hardwood timbers, compared to native forests; and
- The income obtained from harvesting cross-subsidises the costs involved in planting for sequestration, thereby improving the cost-effectiveness of the carbon sequestration.

The results of the research are succinctly summarised in Figure 1, which compares long-term sequestration in perpetual (unharvested) forests and harvested plantations. While unharvested plantations initially sequester more carbon, because they are not subjected to a pruning and thinning regime, they effectively stop sequestering carbon after about 30-40 years. On the other hand, the sequestration in harvested plantations, and their harvest products, keeps increasing at an approximately constant rate (with periodic fluctuations) so long as the plantation continues to be replanted after each harvest.

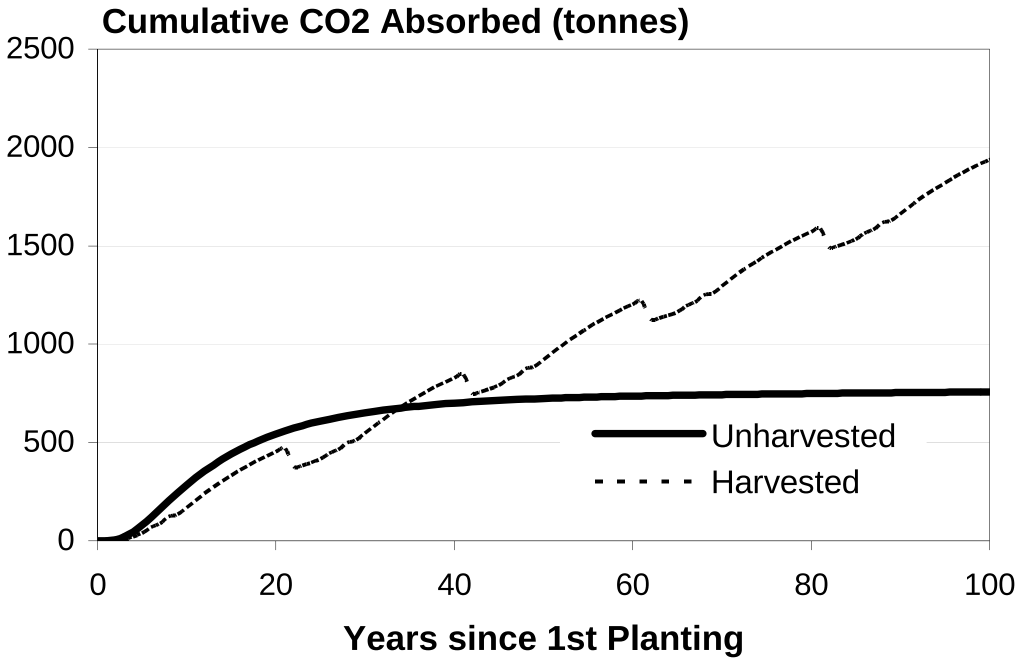

Figure 1 Comparison of Unharvested and Harvested Plantation Sequestration

Taking account of the costs and revenues of establishing and managing unharvested and harvested plantations, and assuming that all costs, revenues AND sequestered carbon is subject to a common economic discount rate (to recognise the fact that costs, revenues and sequestrations that occur this year are worth more that the same costs, revenues and sequestrations occurring in 100 years time) (Boscolo et al, 1998), it has been shown that (over a 100-year project lifetime) harvested plantations absorb more CO_2 than unharvested plantations and do so with a cost-effectiveness that is at least three to four times greater than for an unharvested plantation.

5 The Extent and Cost of Required Offsets

Assume, for the moment, that all the offsetting of land-transport emissions is to be done by way of tree-planting programs in harvested plantations. The question that arises is how much tree planting would need to be done, and how much would it cost? Richardson (2005b) has shown that a harvested eucalypt plantation growing at an average rate of 16 m3/ha/year over a 20-year rotation would sequester an average of about 20 tonnes CO_2 per hectare per year (in the early years of the plantation, the rate of sequestration would be lower than this, but in the middle years of the rotation (year 5-15) the rate of sequestration would be higher than this average rate).

At this rate of tree growth and sequestration (which would be typical of areas with an annual rainfall of 600-700mm), the required hectares of plantation would be as shown in Table 7. The area of plantation required would be inversely proportional to the average rainfall. Under the assumed conditions, approximately 4 million hectares of plantation would be required to offset 100% of the land-transport emissions. To put this in perspective, Victoria would require nearly one million hectares of plantation, and the bushfires in Victoria over summer 2006-07 consumed about 1.3 million hectares of forest. Note that, once planted, these hectares of plantation can be re-used on an ongoing basis to offset emissions in future years, because the increase in sequestration each year is being used to offset the transport emissions each year. This is different to some early models of tree-planting sequestration (e.g. Greenfleet) where one year's vehicle emissions were offset by a lifetime of sequestration in a small number of trees. Such a model will be untenable in future carbon trading schemes, where "future borrowing" of sequestration will not be allowed to offset current emissions.

Table 7 Hectares of Plantation Required for Offsetting by Vehicle Type by State

	State of Vehicle Registration								
Vehicle Type	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	TOTAL
Passenger Vehicles	721171	598698	466193	241018	162249	55827	39288	13679	2298123
Motorcycles	2541	3024	2729	1184	694	204	264	136	10775
Light Commercial Vehicles	182988	121815	152207	65151	41194	20102	5286	8204	596948
Rigid Trucks	104813	77964	90316	30397	18484	8191	2672	3197	336034
Articulated Trucks	112573	161556	128244	48245	49230	11159	2133	4513	517653
Non-Freight Carrying Trucks	2242	4006	2132	1286	404	221	110	147	10547
Buses	23128	17357	17784	9576	5600	1796	1283	2779	79301
TOTAL	1149455	984420	859605	396857	277856	97498	51036	32654	3849380

The required hectares of plantation can also be compared with the existing plantation estate in Australia. Ragg (2007) estimates that 43.7 million tonnes of CO_2 are currently being sequestered each year in Australian productive forests (excluding national forests) and plantations. Thus, the amount required to offset all land-transport emissions would be approximately twice the current total. This estimate is confirmed by the Vision 2020 Plan for Australian Plantations (Plantation 2020 Vision Implementation Committee, 2002) which estimated that the total area of plantations in Australia in 2002 was 1.63 million hectares. Since then, the Bureau of Rural Sciences in the Australian Department of Agriculture, Fisheries and Forestry (BRS, 2007) has estimated that the total area of plantations in Australia in 2006 had grown to 1.82 million hectares (at a rate of about 3% per year). Importantly, the Plantation 2020 Vision is that the area of the national plantation estate should treble from 1997 to 2020, to a total of about 3 million hectares in 2020. Thus the total area required for 100% offset of land-transport emissions in Table 7 (3.8 million hectares) is not out of scale with what is expected to occur.

In addition, there are some areas where considerably greater growth in plantations could occur, such as in the wheat belt in South-West Western Australia where extensive tree planting is required for salinity control purposes to return the land to previous levels of productivity. It has been estimated (Shea, 2003) that of the 18 million hectares of cleared land in the region, it will be necessary to plant between 10% and 30% with deep-rooted perennial crops (trees) to stabilise the rate of increase in salination, giving rise to 3 million hectares of new plantings in that region alone. The goal of offsetting all land-transport emissions with tree planting is clearly ambitious, but not unachievable in a country like Australia with ample land and clear needs for tree planting for other reasons.

The question then arises as to the likely cost of such a tree planting exercise. If the trees are being planted for other reasons, such as salinity control or the production of timber products or bioenergy from harvested plantations, then not all of the cost of planting and maintenance need be borne by carbon sequestration payments (this is another advantage of using harvested plantations that generate other income streams). Rather, the cost of offsetting will be determined by the market price of sequestered carbon. This cost will depend on whether the carbon is being bought in a mandatory market (such as in Europe) or in a voluntary market (such as currently in Australia). The cost in a mandatory market will be higher than in a voluntary market. Even though Australia does not yet have a formal carbon trading system, there are a number of voluntary offset programs in place, where individuals and organizations can offset their emissions. A review of the websites for these programs shows that the average cost per tonne of CO_2 is approximately $12 (this is also the average price submitted in a recent tender process to offset the emissions of the Victorian Government vehicle fleet). If this price of $12/tonne is accepted for the moment, then the total cost for offsetting 100% of land-transport emissions in Australia would be as shown in Table 8. It can be seen that the total cost for Australia would be a little under $1 billion per year.

Table 8 Total Annual Cost ($1000s) for Offsetting by Vehicle Type by State

	State of Vehicle Registration								
Vehicle Type	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	TOTAL
Passenger Vehicles	$173,081	$143,687	$111,886	$57,844	$38,939	$13,398	$9,429	$3,282	$551,549
Motorcycles	$609	$725	$655	$284	$166	$48	$63	$32	$2,585
Light Commercial Vehicles	$43,917	$29,235	$36,529	$15,636	$9,886	$4,824	$1,268	$1,968	$143,267
Rigid Trucks	$25,155	$18,711	$21,675	$7,295	$4,436	$1,965	$641	$767	$80,648
Articulated Trucks	$27,017	$38,773	$30,778	$11,578	$11,815	$2,678	$511	$1,083	$124,236
Non-Freight Carrying Trucks	$538	$961	$511	$308	$97	$52	$26	$35	$2,531
Buses	$5,550	$4,165	$4,268	$2,298	$1,344	$430	$307	$666	$19,032
TOTAL	$275,869	$236,260	$206,305	$95,245	$66,685	$23,399	$12,248	$7,836	$923,851

However, if a mandatory carbon trading system were introduced in Australia, it is likely that the demand for sequestered carbon would increase the price per tonne, as it has done in Europe after the introduced of a mandatory program in 2005. If the price was doubled to approximately $25/tonne, then the cost of a 100% offset would increase to about $2 billion per year. However, most policies are aiming for about 50-60% reduction by 2050, and hence this could be achieved for about $1 billion per year. Given that transport accounts for about 15% of total emissions, this would equate to about $6 billion per year for offsetting 50-60% of all emissions from all sectors of the economy, which is a figure often quoted by other commentators on the costs of climate change action in Australia.

6 Paying for the Offsets

If the cost of offsetting Australian land-transport emissions is about $1 billion per year, a final question is how that cost could be paid, and by whom. It is possible that the cost could be met by Government (perhaps shared between Federal and State Governments) if it was seen that such expenditure was in the national interest. While this is clearly the case, it is unlikely that governments would meet the entire cost of this investment because of perceived budgetary constraints. In addition, it may be perceived as desirable if the costs of the offsets were charged as user-pays contributions, so that the cost of the polluting activities was made more obvious to those parties creating the pollution. In such a situation, three user-pays options present themselves, with payments being charged on a per-vehicle, per-kilometre or per-litre basis.

6.1 Annual Compulsory Environmental Insurance (CEI)

If offset costs were charged to travellers on an annual per-vehicle basis, this could be included in annual vehicle registration charges. Just as Compulsory Third-Party Insurance (CTPI) is automatically added to vehicle registration charges each year to cover the possible personal damage caused to third parties in motor accidents, so a Compulsory Environmental Insurance (CEI) could be added to cover the possible damage caused to the environment through motoring. If the costs of offsetting were spread across all vehicles (within each state and vehicle class), then the CEI annual costs would be as shown in Table 9.

Table 9 Annual CEI Premium for Offsetting by Vehicle Type by State

	State of Vehicle Registration								
Vehicle Type	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	TOTAL
Passenger Vehicles	$52	$48	$54	$49	$43	$50	$50	$46	$50
Motorcycles	$5	$7	$7	$5	$6	$5	$9	$9	$6
Light Commercial Vehicles	$76	$67	$74	$64	$73	$70	$68	$73	$72
Rigid Trucks	$229	$211	$277	$152	$170	$203	$281	$188	$220
Articulated Trucks	$1,743	$1,845	$2,056	$1,391	$1,887	$1,802	$2,344	$1,450	$1,813
Non-Freight Carrying Trucks	$136	$171	$133	$87	$51	$51	$226	$134	$125
Buses	$317	$317	$301	$280	$344	$219	$344	$260	$305
TOTAL	$66	$65	$75	$62	$60	$65	$56	$71	$66

It can be seen that the CEI Premium would vary most dramatically by vehicle class, with relatively little variation across the states. Passenger vehicles would be required to pay an annual CEI Premium of $50 p.a. (compared to about $200-$300 for CTPI, depending on type of vehicle and location of registration), while large articulated trucks would be required to pay a CEI of about $1800 p.a., because of the longer distances travelled and their higher fuel consumption (and hence greenhouse emissions).

While CEI would be relatively simple to administer, since there is an existing administration system in place in all states and there is already a comparable product in CTPI from which to draw experience, it would not be the most equitable system of user-pays charging. Firstly, even though the CEI Premium would vary across vehicles classes as shown in Table 9, it would not automatically allow for differences within a vehicle class. For example, it would be best to have a different CEI Premium for different size vehicles and for vehicles using different fuel types. While this would be possible, it would add to the complexity of the system. Importantly, however, it would not allow for the different usage of vehicles of similar size and fuel type. A vehicle travelling 5,000km/year would be charged the same CEI as a vehicle travelling 50,000km/year. Clearly, such a system would not convey the proper market signals to encourage users to travel less.

6.2 Per-kilometre Offsetting Costs

An attempt could be made to introduce distance travelled into a user-pays CEI charge by charging vehicles on the basis of distance travelled, as shown in Table 10, where the total cost within each state and vehicle class has been divided by the kilometres travelled within that group. It can be seen that the overall CEI cost per kilometre travelled is 0.4 cents/km, rising to 2.0 cents/km for articulated trucks. While it is doubtful that a workable administrative system could be developed to implement these charges (short of fitting each vehicle with a GPS system, as is done in some European heavy vehicle road pricing schemes), Table 10 is useful in highlighting the relatively low cost of CEI compared to the overall costs of motoring. Motoring organizations around Australia (e.g. NRMA, RACV) release figures annually showing the total costs of vehicle ownership and operation. While varying by age and type of vehicle, a figure of 50 cents/km is often taken as a reasonable average cost. This would suggest that the CEI cost (at 0.4 cents/km) is about 1% of the total cost of owning and operating a vehicle. This figure can be confirmed by considering the results from the 2003-04 Household Expenditure Survey conducted by the ABS (ABS, 2006b), in which it was found that the average household spent $140/week on transport (most of which was spent on motor vehicles). This equates to about $7000 p.a. Given that the average household has 1.5 vehicles, which would cost $75 p.a. for CEI Premiums, this again shows that the cost of the CEI is about 1% of the total current expenditure on vehicle ownership and operation.

Table 10 Cost (cents) per Kilometre for Offsetting by Vehicle Type by State

	State of Vehicle Registration								
Vehicle Type	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	TOTAL
Passenger Vehicles	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Motorcycles	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Light Commercial Vehicles	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Rigid Trucks	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Articulated Trucks	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Non-Freight Carrying Trucks	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Buses	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
TOTAL	0.4	0.5	0.5	0.4	0.5	0.4	0.4	0.5	0.4

6.3 Fuel Surcharge Offsetting Payment

The disadvantages of the annual and per-kilometre CEI payments are overcome to a great extent by adopting a per-litre fuel surcharge as a way of meeting the costs of offsetting. This has the advantage of ensuring that the payments made are directly related to the amount of fuel consumed (which will be a function of the type and size of the vehicle and the distance travelled by the vehicle) and can also be varied by the type of fuel consumed (which have different Fuel Factors in terms of kg CO_2/litre fuel). This method also has the advantage that an administrative system is already in place for the collection of various fuel taxes, so that adding the CEI surcharge on top would be a relatively simple procedure.

If the total cost of the offsetting was divided by the number of litres of fuel used in each state and vehicle class, a simple fuel surcharge rate emerges for each type of fuel (since emissions and hence offsetting costs are directly proportional to litres of fuel consumed). For petrol, the CEI surcharge would be 3.1 cents/litre, while for diesel, the surcharge would be 3.6 cents/litre (other fuel types would have their own rates, but they are not calculated in this paper). Given that the average cost of petrol is around $1.30/litre (at time of writing), it can be seen that the CEI surcharge would be less than the daily fluctuations of petrol price at the pump.

So long as consumers saw that the CEI surcharge was actually being used to remove CO_2 from the atmosphere, and was not just another fuel tax, public acceptance of such a payment should be reasonable. A random survey of 1000 Australian households in February 2007 (conducted for TreeSmart Australia by I-view Pty Ltd, as part of their ongoing omnibus surveys) showed that among the 890 licenced drivers in the sample, 70% were willing to pay an extra 3 cents/litre if they knew that the money was going to be used to offset their greenhouse emissions. Those aged under 35 were more willing to pay (83% willing to pay) than those aged over 55 (59%). Those with children in the household were more willing to pay (75%) than those without children in the household (65%).

7 Conclusions

This paper has described what would be required to offset the greenhouse emissions from Australia's land-transport operations. In the context of a model of Carbon Neutrality (the MAORI Model), the central role of offsetting has been highlighted as a way of providing immediate short-term relief from CO_2 emissions, and as a way of encouraging behavioural and technological changes that will be required for ongoing long-term relief.

Using data from the ABS and the AGO, the paper has then estimated the greenhouse emissions from Australian land-based transport (excluding trains and trams), based on:

- The size of the fleet of different vehicle types
- The usage of different types of vehicle
- The emissions from different types of vehicle

It is confirmed that the annual greenhouse emissions from Australian land-transport is about 80 million tonnes CO_2-e.

The paper then outlines a method for offsetting these emissions, based on the planting, maintenance, harvesting and re-planting of plantations across Australia. If all the offsetting was done in this way, then it is shown that approximately 3.8 million hectares of plantation would need to be established. This amount is compared with existing plantation areas, and plans for future expansion of the number of plantation hectares, and is shown to be not an unreasonable target in the Australian context.

The cost of offsetting by tree-planting is then explored, and it is shown to cost around $1 billion/year at current carbon costs, and perhaps $2 billion/year at future costs, for offsetting 100% of land-transport emissions. Options for paying for this offsetting are then explored in the context of various user-pays schemes. It is shown that an annual Compulsory Environmental Insurance (CEI) included in vehicle registration charges would cost around $50 p.a. for passenger vehicles. A per-kilometre CEI charge would be around 0.4 cents/km for passenger vehicles, and this is shown to be only 1% of current household expenditures on vehicle ownership and operation. A per-litre fuel surcharge to cover CEI would be 3.1 cents/litre for petrol and 3.6 cents/litre for diesel.

While the total costs of the offsetting appear to be quite large ($1 billion p.a.), the costs at the level of the individual are very modest when considered on a per-vehicle. per-kilometre or per-litre basis. The question is not about whether we can or should offset our transport greenhouse emissions, the question is about what is the most convenient way to do so.

We all have a responsibility to do something about our own transport emissions, and this paper has shown that it is quite reasonable and feasible to do something. It will not cost the earth to save the earth.

In the words of John Kennedy Snr. (legendary coach of the Hawthorn Football Club) in his half-time address to Hawthorn players in the 1975 Grand Final (in which Hawthorn was well behind), "Don't think! Don't hope! Do Something!".[1]

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[1] Students of Australian Rules football may know that Hawthorn did not go on to win the 1975 Grand Final – they were just too far behind at half-time. We may find the same applies to global warming – we may have left our run too late to rectify the situation, but if we do our bit and apply the MAORI model to our own emissions, we can at least say we "did something"!

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