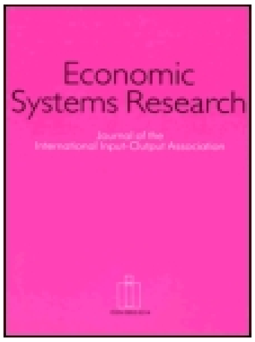

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AUSTRALIA'S CARBON FOOTPRINT

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This paper gives an overview of the construction techniques and methods used to assign greenhouse gas accounts to industry sectors and of the use of input–output analysis to subsequently calculate the carbon footprint of Australia. The work is motivated by the introduction of an emissions-trading scheme in Australia, and by the need for policy to be developed around the direct and indirect (life-cycle) greenhouse gas emissions of industries, especially with regards to the trade exposure of industries with large carbon footprints. Greenhouse gas multipliers, which show the carbon footprint intensity of consumption items, are calculated to gain insight into opportunities for 'greening' consumption. Key industries are identified in relation to both greenhouse gas emissions and economic importance. The effects of imports, exports and capital consumption are explored and a brief analysis of the change in greenhouse gas multipliers over time is given.

Keywords: Australia; Input–output analysis; Carbon footprint; Greenhouse gas emissions; Sectoral analysis

1 INTRODUCTION

In this paper we present an inventory of the carbon footprint of the Australian economy. Our work goes beyond currently available emission inventories by using detailed economic and physical data to generate a higher level of detail in the emission inventory, and by relating the responsibility of these emissions from producer to consumer by means of input–output analysis.

The carbon footprint as used in this paper is defined as the total "basket of six"[1] greenhouse gas emissions (not just carbon dioxide emissions. cf. Wiedmann and Minx, 2008) embodied in the goods and services required by current final demand. By using a footprint methodology, we are, in essence, assigning all responsibility of greenhouse gas emissions generation to consumers instead of producers (Peters, 2008). This is in line with traditional economic thinking of demand-driven production.

The carbon footprint is also a popular tool for individuals, populations and other entities to investigate their individual or collective consumption and to analyse which items of consumption embody the most greenhouse gases (Weber and Matthews, 2008; Hertwich and Peters, 2009; Minx et al., 2009). The publication of footprint results by type of good or service is of value in helping consumers to 'green' their consumption – enabling shifts from more to less greenhouse-gas-intensive products. Within a product carbon footprint,

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[1] Carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

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a life-cycle approach (Finkbeiner, 2009; Weidema et al., 2008) is taken implicitly in the calculation of the footprint for each item consumed by a population.

Measures of greenhouse gas emissions (in carbon dioxide equivalents, CO_2-e) presented in this study are:

- production approach – greenhouse gas emissions produced directly by industry (scope 1 under the Greenhouse Gas Protocol Corporate Standard – World Resources Institute and World Business Council for Sustainable Development 2004); and
- consumption approach – embodied greenhouse gas emissions by industry, i.e. the indirect or life-cycle greenhouse gas emissions required in the production of goods and services. Embodied emissions are expressed in relation to final demand as the functional unit.

Because of the importance of emissions from electricity production, these emissions (known as scope 2 in the Greenhouse Gas Protocol) are handled explicitly, and calculated separately:

- scope 2 greenhouse gas emissions by industry, i.e. emissions generated in the production of electricity used by each industry; and
- embodied electricity emissions by industry, i.e. the life-cycle greenhouse gas emissions solely from electricity production, which are required in the production of goods and services.

The objectives of this work require an approach that is consistent with national accounts data for both the economy and greenhouse gas emissions, whilst being able to comprehensively cover all processes that embody greenhouse gas emissions in final demand. In order to accomplish this, the tool of input–output analysis has been employed. Australian input–output tables are consistent with national accounts data, whilst allowing the tracking of greenhouse gas emissions from industry sources through the production system to types of final demand. That is, input–output analysis allows a life-cycle approach to the calculation of emissions embodied in the goods and services consumed by Australia's population.

Input–output analysis is a macroeconomic technique that uses data on inter-industrial monetary transactions to account for the complex interdependencies of industries in modern economies. Since its introduction by Leontief (1936, 1941), it has been applied to numerous economic and environmental issues (Miller and Blair, 2009), and input–output tables are now compiled on a regular basis for most industrialised, and also many developing countries.

Greenhouse gas emissions in units of tonnes are allocated as exogenous inputs into each industry, and subsequently allocated throughout the production system by means of economic requirements – i.e. emissions are passed on from one industry to another proportionally to the economic flows between industries. The advantage of this approach is that price impacts associated with carbon cap and trade plans will likely be conveyed throughout the economy in a way similar to the modelled allocation. That is, the addition of a cost of emitting greenhouse gas emissions will likely be transferred to consumers as an additional margin to current costs of production, not as a margin to the current volumes of goods/services being used in production. Methods of allocation based on physical data (e.g. through physical input–output analysis or material flow allocation:

see Giljum and Hubacek, 2004 for an overview), whilst perhaps better at allocating environmental pressures to material throughput, are not as closely aligned to the economic basis of decision making and policy development concerning carbon trading and carbon taxation.

We briefly outline the required variables and calculations in Section 2, before describing the methods and assumptions we made for constructing an integrated database. An examination of major trends is presented in Section 4 before conclusions are drawn in Section 5. For background, basic input–output theory is provided in Appendix 1. Appendix 2 contains details of the allocation of greenhouse gas emissions to industry sectors.

2 CALCULATIONS OF EMISSIONS

2.1 Domestic Emissions

We focus on domestic emissions first and subsequently address emissions embodied in imports and exports in the context of national carbon footprint accounting (see Sections 2.2 and 2.3). This is because domestic emissions are currently considered the basis for policy development in Australia (Department of Climate Change, 2009). We therefore align sector level emissions data with Australia's National Greenhouse Gas Inventory (NGGI) under the United Nations Framework Convention on Climate Change. Direct (scope 1) emissions from all industrial sources are denoted $\mathbf{Q1}^{ind}$ (see Appendix 1).

The direct emissions intensity of domestic production is then calculated to describe emissions by industry sector per value of economic output of each industry sector. This intensity represents only emissions produced directly in each industry, but not in upstream supplying industries. A high emissions intensity shows that an industry directly produces large quantities of greenhouse gas emissions per $ of its production value.

Total embodied emissions are then defined as all greenhouse emissions emitted in the production of a particular good or service. They are the full life-cycle emissions for the entire production chain and are referenced by the functional unit of final demand for the good or service. Total embodied emissions by category of final demand are calculated using the basic input–output relationship (see Appendix 1). Final demand is the end point of all domestic production, thus no double counting of emissions occurs. If a functional unit was chosen that is an intermediary stage of production (such as a factory or retailer) either some form of subjective allocation (Gallego and Lenzen, 2005) of emissions must occur, or emissions nationwide would be double counted. Final demand differs from (current) private consumption in that allowance is made for public consumption, capital formation, changes in stocks and goods and services going to export. The use of final demand as a functional unit is convenient, as it represents a single point where products are no longer processed domestically, thus avoiding double counting of embodied emissions. The inclusion of exports in final demand is necessary (not only from a national accounting point of view) but because there are no data available to separate production processes for goods going to export compared with those going to other forms of final demand.

Scope 2 emissions ($\mathbf{Q}^{elec}$) refer to emissions only from electricity supply. Electricity supply is distinguished so that it can be treated as a direct flow, consistent with its treatment under the NGGI. This increases the accuracy of emissions allocation, as electricity-related emissions allocated by physical usage rather than relying on distribution by economic units within the input–output model.

In calculating embodied electricity emissions explicitly within the Scope 1 framework, it is necessary to redistribute $\mathbf{Q1}^{ind}$ of electricity using the physical allocation of emissions, $\mathbf{Q}^{elec}$, across the economy. That is,

$$\mathbf{Q}^{ind} = \mathbf{Q1}^{ind}_{i=1:n, i \neq elec} + \mathbf{Q}^{elec}$$

The calculation of total embodied emissions including the direct allocation of electricity emissions then proceeds as per standard input–output analysis (refer to Appendix 1).

2.2 Calculations of Emissions Embodied in Imports

The importance of imports in assessing the carbon footprint of a nation has been a recent focus of research (Peters and Hertwich, 2006; Wiedmann et al., 2007, 2010; Hertwich and Peters, 2009). For some countries, emissions embodied in imports are greater than domestic emissions. Ideally, a model can be employed that explicitly accounts for production processes in all trading partners of a country. The models most commonly used are multi-regional input–output (MRIO) models. However, an approximation on emissions embodied in imports can be made by using a 'domestic technology assumption', which assumes that imported goods are produced under the same technology as domestic goods.

Some criticism has been made of using the domestic technology assumption compared with a full MRIO model. In Australia's case, the import demand is much lower than for other countries, which makes the effect of the assumption much smaller. The difference in the aggregate national carbon footprint estimated in a 57-sector model (see Andrew et al., 2009) was about 9% greater under the domestic technology assumption compared with a full MRIO model. Further, the model we employ describes technology in significantly more detail than any existing MRIO model (344 sectors here compared with 57 sectors in current MRIO models, for example: Andrew et al., 2009; Hertwich and Peters, 2009). Hence the different technologies used by Australia's trading partners are already accounted for to some extent with the higher detail used within this study. Using a more aggregated MRIO could just as easily give misleading results if emissions intensive sectors are aggregated. The one sector that has a significantly different emissions intensity globally is electricity supply, and we calculate these emissions separately from other emissions so misleading results can be identified. The calculation of emissions embodied in imports as per the domestic technology assumption is described in Appendix 1.

2.3 Calculations of Emissions Embodied in Exports

As with imports, the knowledge of emissions going to export is essential for assigning a carbon footprint to the population of Australia. Whilst the notion of a carbon footprint includes responsibility for imported goods and services, it also implies that exported goods and services are the responsibility of the importing country (i.e. of consumers abroad), and hence should be subtracted from domestic footprints.

The estimation of emissions embodied in exports is straightforward due to the identification of exports as a destination of final demand. It is noted that imported goods can also be subsequently exported, and are also included here (see Appendix 1).

2.4 Calculations of the Carbon Footprint

The national carbon footprint of Australia is then simply domestic greenhouse gas emissions plus greenhouse gas emissions embodied in imports and minus greenhouse gas emissions embodied in exports. The carbon footprint is generally expressed as a per-capita figure.

3 DATA SOURCES AND ALIGNMENT

A key issue in calculating a meaningful carbon footprint is the level of detail on sector disaggregation. The more aggregated a dataset the less useful it is for policy formation, and the less accurate it is for analysing specific goods and services. A reduction in sector resolution can significantly limit the resulting model for impact analysis and decision making, especially when investigating boundaries between economic and non-economic indicators. It is generally desirable to use the maximum level of detail in compiling the system, and aggregate results after impact analysis, if necessary.

The principal reason for working at a high level of detail is that physical data used for allocating emissions is often available at varying levels of detail for different industry sectors depending on the subject being investigated. Hence, in calculating footprints, we are seeking 'holistic accuracy' – that is, the accuracy of the overall model and its most influential components rather than precision of individual elements (Jensen and West, 1980; Hewings et al., 1988; Gallego and Lenzen, 2008).

To highlight the issue of accuracy (compare Gallego and Lenzen, 2008), we note that the greenhouse gas emissions allocated to beef cattle are considerably different from the greenhouse gas emissions allocated to sheep farming. If, as is common in basic data, the beef cattle industry is aggregated with sheep farming in a 'livestock' industry, it is not possible to discern the difference in the greenhouse gas intensity of the two industries. The consumption of livestock products will embody a large quantity of greenhouse gases, even if, in reality, all consumption was from sheep products and none from beef cattle. This is important in Australia's situation, where large changes in sheep and cattle farming are occurring in opposing directions (increase in beef production; decrease in sheep production) and are often destined for different levels of demand, domestically and for export. In an aggregated framework, the specific detail of the different practices is not captured, whereas aggregation after analysis will include these differences. An empirical study demonstrating this effect is found in Lenzen et al. (2004).

Thus, an important part of calculating carbon footprints is the allocation of emissions data to end use categories. Various assumptions must be made to disaggregate emissions data, and these must be done so as not to compromise the holistic accuracy of the analysis. The importance of the work is twofold – first, economic data must be at sufficient detail in order to distinguish economic flows with differing greenhouse gas intensities and, second, greenhouse gas emissions data must be disaggregated to individual economic sectors.

The disaggregation of economic flows is described elsewhere (Wood, 2009). Here, we describe the disaggregation and allocation of greenhouse gas emissions, particularly for the Australian case.

3.1 Data Sources

Three main data sources have been used in this study. First, input–output data has been generated as per Wood (2009). The input–output data was a combination of the published input–output tables and more detailed product level data (Australian Bureau of Statistics, 2008). The product level data was integrated so as to give structural detail on emissions intensive sectors such as aluminium. Secondly, the ABARE publication *Australian Energy Consumption and Production 1974–75 to 2004–05* (Australian Bureau of Agricultural and Resource Economics, 2006) was used to delineate fuel combustion energy emissions, by using higher levels of detail of energy data and by using industry-specific equipment types, emission factors and fuel types. Third, the *National Greenhouse Gas Inventory* (NGGI – Australian Greenhouse Office, 2008b) has been the key source of data on greenhouse gas emissions. Additional data sources have been used in the disaggregation of energy and emissions data in order to align them with the economic sector classification, and these are described in detail in Appendix 2. A publicly available database showing the end results of the transformations is available (Dey et al., 2008).

The NGGI database distinguishes six types of greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) and six categories of emissions (fuel combustion, industrial processes, solvent and other product use, agriculture, land use change and forestry, and waste). Within these six categories, there are a varying number of sub-classifications, of which some conform directly to input–output classifications, and some of which report on processes common to a number of input–output classifications.

Fuel combustion emissions were allocated according to the specified industries. Agricultural and land use change emissions were allocated mainly following the methodology employed by George Wilkenfeld & Associates Pty Ltd and Energy Strategies (2002), but necessarily updated to more recent allocation factors due to the significant changes in agricultural practices over time. In addition, the NGGI publishes a database allocated to standard industry sectors, along with allocation factors. Where these data were superior to other available data, these allocations were employed. Finally, where disaggregated data were not available, it was necessary to use other proxies (such as production value, employment, production volume, etc) in order to allocate emissions. These assumptions are described in Appendix 2. Reference is made to the NGGI classification of sectors as per UNFCCC accounting conventions.

For this work, 344 sectors were distinguished, representing one of the highest levels of sector detail in environmental-economic modelling. However, this is not to say that all results should be interpreted at the 344 level of detail. Utilising a model that crosses economic and environmental disciplines means that some detailed data will be important within one discipline whilst almost negligible in the other discipline. Hence, whilst industries may be important economically, if they have small environmental consequences they are likely to have very high uncertainty associated with their environmental data. However, from a modelling point of view, they mean very little in the overall

TABLE 1. Overall results for Australia, 2005. Scope 1 excludes emissions from electricity supply which are accounted for within Scope 2.

	Emissions excl electricity (Mt)	Emissions from electricity (Mt)	Total (Mt)	Total per-capita (Mt/capita)
Total Domestic GHG emissions	387.7	194.1	581.9	28.6
+ Emissions embodied in imports	79.6	63.1	142.7	7.0
− Emissions embodied in exports	148.9	53.3	202.3	9.9
= national carbon footprint	381.6	203.9	522.4	25.7

interpretation of results. We concern ourselves with holistic accuracy by focusing on this detail rather than by increasing precision on inconsequential flows. The specifics of how the greenhouse gas data were allocated following this principle can be seen in Appendix 2.

4 RESULTS AND DISCUSSION

4.1 Summary

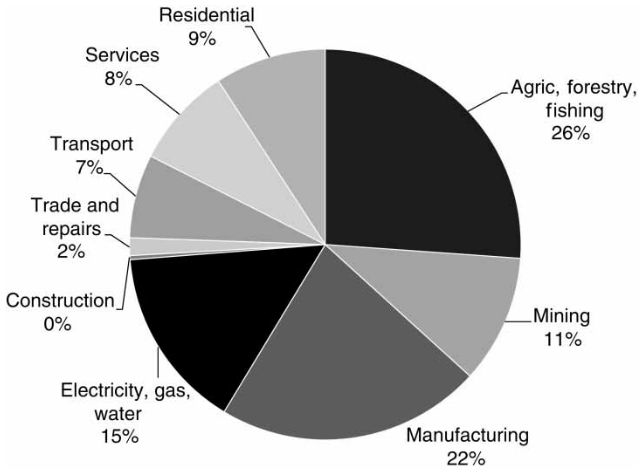
The top level results for Australia are presented in Table 1. In 2005, overall domestic emissions were 581.9 Mt, with 194.1 Mt being from electricity supply (scope 2), equating to a per-capita level of 28.6 Mt.[2] Emissions embodied in imports are estimated at 142.7 Mt, of which about 60 Mt came from electricity. These electricity emissions are probably overestimated, as Australian technology is assumed, and the Australian electricity supply is predominantly coal fired (which has a higher emissions intensity than most other foreign electricity producing technologies). Emissions embodied in exports are estimated at 202.3 Mt, with 53.3 Mt being from the electricity supply. It is interesting to note that whilst policy is generally focused on emissions-intensive, export-oriented industries such as mining, of the order of 25% of Australia's predominantly coal-fired electricity will be embodied in goods and services consumed overseas. The estimated carbon footprint of demand in Australia is 522.4 Mt or 25.7 Mt/capita, slightly less than domestically produced emissions (581.9 Mt or 28.6 Mt/capita).

4.2 Sector Emissions, 2005

The direct emissions allocated to the producing sector are shown in Figure 1 for 2005. These are the emissions as reported by Australia under the Kyoto Protocol (United Nations, 1992), representing $\mathbf{Q}^{ind}$. As expected, the importance of primary industries is high, with over one-third of total emissions. Manufacturing and utilities make up an additional third. Thus, even with the almost complete reliance on coal for electricity generation in Australia, these emissions only make up less than 15% of the total. A significant issue for Australia is the prominence of agricultural and mining emissions. These emissions occur in non-urban areas and are caused by industry supporting rural

[2] Consistent with the 2008 NGGI (Australian Greenhouse Office, 2008b).

FIGURE 1. Direct greenhouse gas emissions by industry, Australia 2005.



communities. As these industries often have significant social and economic benefits, the only politically palatable option to address these emissions is to seriously focus on efficiency, management and technology improvements.

Applying the notion of the carbon footprint to the direct emissions means allocating these emissions to the final commodities produced by industrial sectors. We observe a shift towards products from tertiary production. Figure 2 shows emissions embodied by categories of final demand and include imports but exclude exports.

From a footprint or consumption perspective, manufacturing products contribute over one-third of total emissions. Within manufacturing, the main emissions (cf. Table 2) are from agriculture (primarily associated with beef cattle), embodied within the manufacturing of food. Electricity emissions (going directly to final demand) contribute roughly 14% of the total, whilst direct residential emissions (transport, cooking, etc) are around 9%. Together, residential and electricity emissions are usually considered the main impact

FIGURE 2. Carbon footprint of final goods and services by industry, Australia, 2005.

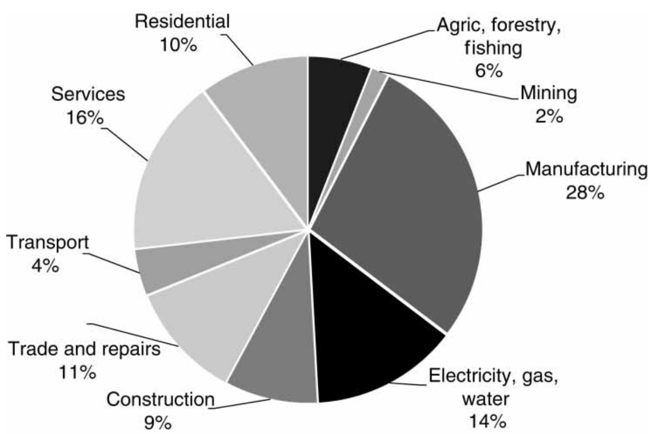


TABLE 2. Carbon footprint by sector of final demand, Australia, 2005.

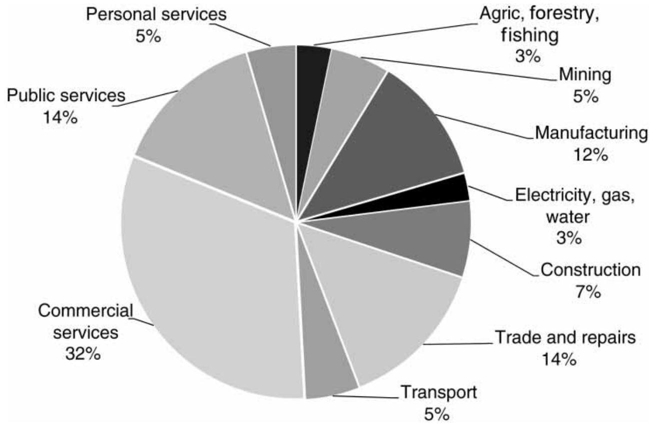
Rank	Carbon footprint, detailed sector	Mt CO_2-eq
1	Electricity supply	66.2
2	Residential	53.5
3	Beef cattle	24.5
4	Retail trade	23.6
5	Fresh meat	18.0
6	Residential building construction	16.4
7	Hotels, clubs, restaurants and cafes	15.7
8	Wholesale trade	13.2
9	Sanitary and garbage disposal	12.9
10	Finished cars	10.4
11	Non-residential building construction	10.2
12	Meat products	10.0
13	Road freight	8.1
14	Non-building construction	7.5
15	Air and space transport	7.4
16	Defence	7.4
17	Dairy products	7.1
18	Real estate agent services	6.4
19	Ownership of dwellings	6.1
20	Electronic equipment	5.9
TOTAL CARBON FOOTPRINT		522

of the population, whilst, in this approach, we see they miss around three quarters of the total impact.

Whilst some of these sectors contribute significantly to greenhouse gas emissions, they also contribute significantly to the economic well being of Australia. If Australia is to move to a lower carbon society, it would be the intention of good policy to support production in sectors that have large social and economic contributions and small environmental impacts. To investigate the social and economic contributions we use the income approach to measuring GDP. Summing over value added (operating surplus, employment & taxes), we compare the relative contribution of each sector to overall GDP in Australia (Figure 3). By doing so, we see that Australia is a service-oriented society in economic terms with roughly 50% of value added coming from the service sectors compared with 8% of emissions production (Figure 1) and 14% in terms of the carbon footprint (Figure 2). In contrast, Manufacturing contributes only 12% to value added, whilst producing 22% of Australia's emissions, and has a carbon footprint of 28%.

The Australian Government is using Value Added as one proxy for determining permit allocations and possible compensation under its forthcoming emissions trading scheme, known as the Carbon Pollution Reduction Scheme (CPRS). Although there are thresholds for the sizes of businesses included, under the draft CPRS, much of the manufacturing, transport and primary industries will, as expected, require significant emissions permits. In addition to the emissions calculations, the Australian Governments is currently examining the level of trade exposure of Australian industries (Department of Climate Change, 2009). As employing a carbon footprint measure assigns responsibility to the consumer (within Australia in this case), it can be misleading to look only at the overall carbon footprint results without looking at the effect of the emissions embodied in the trade flows.

FIGURE 3. Value added (% of profit, employment & taxes) by industrial sector, Australia 2005.



Using the detailed industry classification, it is possible to inform consumers of specific areas where they can reduce consumption in order to affect change in emission levels (Table 2). Whilst the obvious area of curtailing electricity use and fuel use (residential) rank first and second, meat and dairy goods are also of high importance. Some capital-oriented goods, such as cattle, and construction also dominate this ranking. Whilst not items of current consumption, in an accounting sense, they are still attributed to current footprints, as we investigate in the next section.

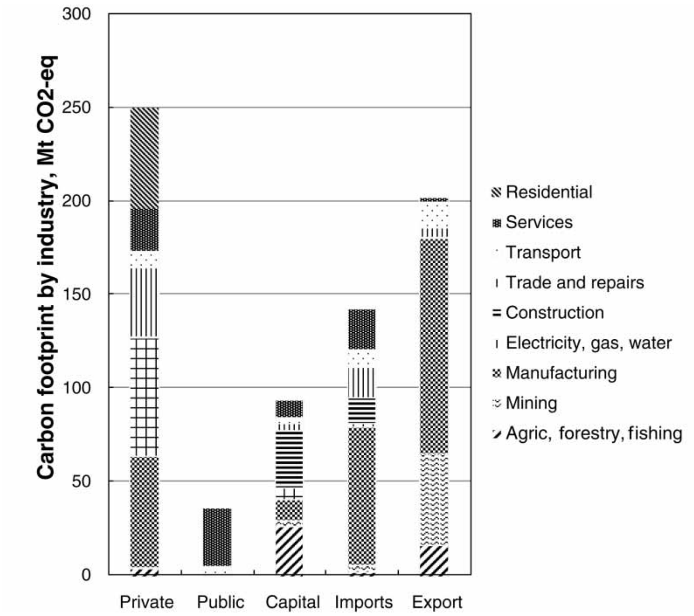
4.3 Imports, Exports and Capital Demand

The production of greenhouse gas emissions in Australia is not driven solely by the consumption of residents in Australia. As previously mentioned, in addition to current consumption, emissions are also embodied in exports for foreign consumers (the carbon footprint of exports from Australia), plus emissions are embodied in purchases for the common good (public/government consumption), and in goods and services flowing into capital formation. These categories of final demand, along with imports, are disaggregated in Figure 4.

This gives a more accurate view of the sector disaggregation in a carbon footprint. The effect of exports on the structure of emissions inventories is evident through the 90% of emissions embodied in exports being within primary and manufacturing industries. Often, these goods are further processed in the destination countries before being made into consumer items. Within private final consumption, we see manufactured goods and utilities almost equal contributors to the carbon footprint. However, considerable greenhouse gas emissions are embodied in manufactured goods imported into Australia. These emissions are mainly due to vehicle production.

The issue of exports deserves some further investigation, as current climate policy appears still to be driven mainly by trading within individual nations rather than towards a global emissions trading scheme. As such, it is intriguing to know which industries are likely to be most affected on the international market when (a) domestic carbon cap and trade policies are introduced or (b) international consumers begin to re-consider

FIGURE 4. Carbon footprint by type of final demand and by imports (NB: exports are not included in the calculation of the national carbon footprint), Australia 2005.



where they import goods and services from. A production approach to emissions inventories will not pick up emissions within the production chain. Only a life-cycle approach, as employed, here will show which exporting industries are most vulnerable to potential flow-on effects from the costs added to producers by cap and trade policies. The breakdown (Table 3) shows, perhaps surprisingly, the meat-producing sector to be of highest importance, due to the emissions produced in livestock rearing. Other bulk energy and mineral producers are also responsible for a significant amount of embodied emissions going to export. The emissions embodied in the transport requirements of exported goods are also evident in the road and air freight sectors. In Australia, the government is currently putting considerable focus on the mining sectors and the mineral products sectors, which rank highly in these results. Under the first iteration of the emissions trading scheme, agricultural emissions may not be included, and hence the meat related industries identified here will not be affected.

4.4 Domestic Greenhouse Gas Emission Multipliers, 2005

Multipliers of final demand in Australia were calculated in order to show the sectors with the highest impact per $ of demand in Australia (Table 4). Multipliers differ from intensities in that multipliers show the total life-cycle emissions associated with each $ of final demand, whereas intensities show only direct emissions per $ of production value. Multipliers are thus the basis of all footprint calculations, and the value of the multipliers shows the carbon footprint per dollar of expenditure. Generally, the breakdown is similar to Table 2, with the largest multipliers being from the products produced by the meat, mineral and

TABLE 3. Emissions embodied in exports by industry sector, Australia 2005.

Rank	Embodied emissions in exports, detailed sector	Mt CO_2-eq
1	Fresh meat	30.8
2	Black coal	28.9
3	Aluminium	21.5
4	Copper, silver, lead, zinc	12.2
5	Alumina	11.4
6	Liquefied petroleum and natural gases	11.0
7	Meat products	6.0
8	Shorn wool	5.8
9	Iron and steel semi-manufactures	5.7
10	Road freight	4.7
11	Air and space transport	4.5
12	Beef cattle	4.2
13	Iron ores	3.2
14	Wheat	3.0
15	Raw sugar	2.7
16	Offal, hides, skins, blood meal	2.5
17	Wholesale trade	2.3
18	Non-ferrous non-aluminium semi-manufactures	2.0
19	Nickel	2.0
20	Copper concentrates and ores	1.8
TOTAL EMISSIONS EMBODIED IN EXPORTS		202

TABLE 4. Domestic multipliers of greenhouse gas emissions relative to final demand (kg CO2-eq/$ final demand).

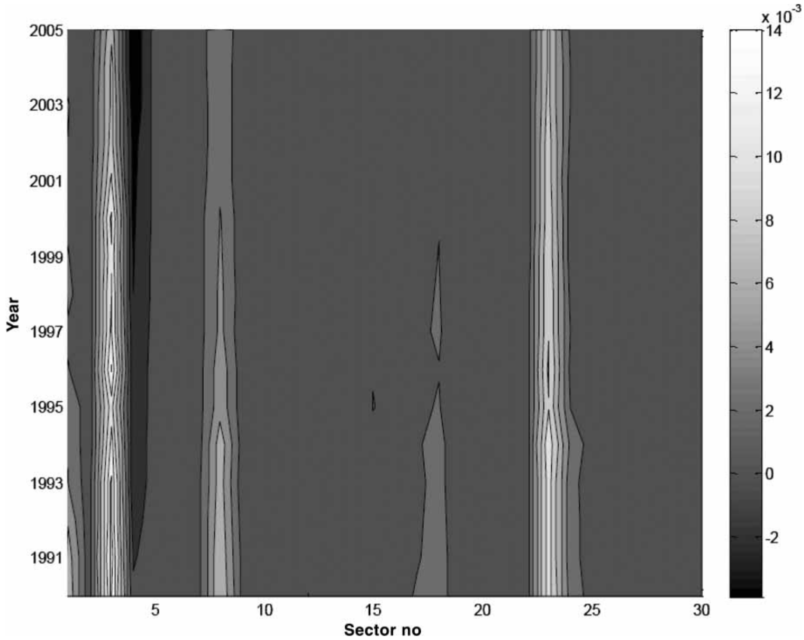
Rank	Footprint multiplier, detailed sector	Mt CO_2-eq/$y
1	Beef cattle	12.9
2	Aluminium	9.3
3	Sanitary and garbage disposal	8.5
4	Meat and meat products	6.4
5	Electricity supply	5.8
6	Nickel	5.2
7	Sugar Cane	5.1
8	Nickel ores	4.1
9	Other property services	4.1
10	Cement, lime and concrete slurry	3.8
11	Sheep	3.7
12	Alumina	3.3
13	Liquefied petroleum and natural gases	3.1
14	Gold	3.0
15	Pigs	2.4
16	Ground minerals	2.3
17	Rice	2.3
18	Dairy products	2.0
19	Iron and steel	2.0
20	Basic chemicals	2.0

electricity industries. It should be noted that these multipliers represent the total embodied domestic emissions per $ of all final demand in Australia. It is assumed that production processes of goods for export are the same as those for domestic consumption. Hence, the ranked list of multipliers includes a number of high ranking goods, such as aluminium, that are more applicable to exported goods rather than domestic final consumption. These data thus have two main purposes – first, for consumers seeking to reduce their consumption, they should seek to avoid goods or services that rank highly in the multiplier ranking. Secondly, export-oriented industries producing products with large multipliers will be sensitive to competition from overseas under a domestic emissions trading scheme that does not take into account carbon leakage (the potential off-shoring of polluting industries); and under an international emissions trading scheme, their costs of production are likely to rise due to price increases associated with emissions being transferred to their goods.

4.5 Evolution of Greenhouse Gas Emission Multipliers

We have calculated the evolution of greenhouse gas multipliers since the start of GHG reporting under the UNFCCC in 1990, by employing the method described above for all years from 1990 to 2005. In Figure 5, the final demand multipliers are mapped into an aggregated model of 30 sectors. This figure shows the changes in direct and indirect production patterns in Australia over time. Lighter shades show high multiplier values (right axis), so darkening implies lesser overall embodied emissions. This figure is designed to give a representation of evolution of the economic structure of Australia. As such, the figure is organised to show primary industries on the left and tertiary

FIGURE 5. Evolution of greenhouse gas emission multipliers in Australia from 1990 to 2005, depicted in a 30-sector aggregation. All values relative to 2005 (dimensionless), with the shade representing the ratio of multipliers in each year to the 2005 multiplier.



sectors on the right. All industries are represented but major change is only seen in relatively few sectors of the economy – mostly sectors in primary industries, and utilities. Beef cattle (leftmost) and electricity production (sector 23) are the two most important sectors, with the changing land practices in beef cattle farming evident in the fluctuating multiplier values (denoted by changing shade intensity). The liberalisation of the electricity markets in the mid 1990s is evident in the change in that multiplier (sector 23). The mining sector (sectors 7–8) has also shown positive change, evolving slightly to be less greenhouse gas intensive. And small improvement can also be seen in manufacturing (sectors 17–18 showing mineral and metallic products).

5 CONCLUSIONS

This paper has presented the results of a national carbon footprint of Australia as well as the methods used to estimate greenhouse gas emissions by industry category. The importance of addressing greenhouse gas emissions, the requirement for consistency from the perspective of national accounting conventions, and the need for measures of emissions embodied in import, export and various consumption categories drove this research. A range of proxy data was used in order to break down aggregate emissions into categories relevant to footprint analysis. Measures of greenhouse gas emissions were presented for emissions due to domestic production, emissions embodied in imports and exports and emissions embodied in capital formation. Emissions were calculated by industrial sector, with 344 sectors used in the most disaggregated form of the model. A few key sectors, particularly beef and electricity, produce the majority of Australia's domestic emissions, whereas emissions embodied in consumption (the carbon footprint) show the higher importance of manufacturing and tertiary sectors. Apart from electricity and direct residential emissions (which together account for about 25% of the total carbon footprint), meat, trade and construction were other key sectors from a carbon footprint perspective. Significant emissions are embodied in the export production of the mining and manufacturing industries. Specific policy is being established within Australia to try to prevent adverse effects of an emissions trading scheme on the competitiveness of these industries in the international marketplace. Although very few of the emissions-intensive industries contribute significantly to GDP, most are based in non-urban areas whose socio-economic stability is highly dependent on these industries.

In terms of policy relevance, the contrasting viewpoints of emissions inventories (production perspective) versus carbon footprints (consumption perspective) are useful for examining the implications of any policy that places a cost on carbon. Although agriculture is likely not to be included in the Australian emissions trading scheme initially, the high emissions intensity of the agricultural sectors is currently a major source of political debate and unease in rural areas. A carbon footprint analysis, as presented here, can inform more rational discussion about what proportions of emissions permit costs can realistically be passed on to processors and ultimately to consumers, and the extent of any negative trade implications. Past experience of the increasing cost and scarcity of water for agricultural purposes, which has meant significant food price increases, represents a similar precedent to the effects of a price on carbon.

A carbon footprint broken down by different elements of final demand also gives insights into some of the differences between Australia's commodities bound for export markets, often with less value adding, and the commodities that go through higher levels of transformation for domestic use. One example of this is a comparison between direct livestock exports (live trade) and domestic consumption of meat products. Much greater economic benefits could be reaped at minimal additional environmental cost if greater levels of transformation were applied prior to export.

Some other important policy considerations for new emissions trading schemes are the amount and allocation method for emissions permits, and, related to this, the amount of compensation paid by governments to industries predicted to have changes in the value of their assets and/or profitability. Overly focusing on sources of direct emissions in policy development, and downplaying the connectedness and dynamic nature of economies, may not lead to the optimum overall outcome that emissions trading schemes are intended to achieve: significant and ongoing emissions reductions at lowest abatement costs with minimum social and economic disruption.

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APPENDIX 1

The Scope 1 direct emissions intensity of domestic production is defined as:

$$\mathbf{q1}^{\mathrm{ind}} = \mathbf{Q1}^{\mathrm{ind}}\,\widehat{\mathbf{x}}^{-1} \tag{1}$$

where $\mathbf{q1}^{ind}$ is the vector of direct emissions intensity. Its elements $\left\{q1_j^{\mathrm{ind}}\right\}_{j=1,\ldots,n}$ describe emissions by industry sector j per A$ value of total output $\mathbf{x}$ of industry sector j. $\mathbf{q1}^{\mathrm{ind}}$ represents only emissions produced directly in each industry, but not in upstream supplying industries.

A vector of total embodied emissions by category of final demand $\mathbf{Q1}^{\mathrm{emb}}$ is calculated according to the basic input–output relationship as

$$\mathbf{Q1}^{\mathrm{emb}} = \mathbf{q1}^{\mathrm{ind}}\left(\mathbf{I} - \mathbf{A}^{d}\right)^{-1}\widehat{\mathbf{y}}_{d} \tag{2}$$

where $\widehat{\mathbf{y}}_{d}$ is a diagonalised matrix of the vector of domestic final demand, $\mathbf{A}^{\mathbf{d}}$ is the (domestic) direct requirements matrix and $\mathbf{I}$ is the $n \times n$ identity matrix. Its elements $\left\{I_{ij}\right\}_{i=1,\ldots,n;j=1,\ldots,n}$ are $I_{ij} = 1$ if $i=j$, and $I_{ij}=0$ if $i \neq j$. $\mathbf{Q1}^{\mathrm{emb}}$ refers to the total emissions from all sources embodied in the goods and services consumed within domestic final demand.

Scope 2 emissions $\mathbf{Q}^{elec}$ refer to emissions only from electricity supply. Scope 2 direct emission intensity is defined as:

$$\mathbf{q}^{elec} = \mathbf{Q}^{elec}\,\widehat{\mathbf{x}}^{-1} \tag{3}$$

$\widehat{\mathbf{x}}^{-1}$ is the inverse of the diagonalised gross output $\mathbf{x}$. Total embodied electricity emissions are calculated as:

$$\mathbf{Q}_{elec}^{emb} = \mathbf{q}^{elec}\left(\mathbf{I} - \mathbf{A}^{d}\right)^{-1}\widehat{\mathbf{y}}_{d} \tag{4}$$

$\mathbf{Q}_{elec}^{\mathrm{emb}}$ refers to the total emissions from electricity generation embodied in the goods and services consumed within final demand.

When calculating emissions associated with electricity generation within the Scope 1 framework, it is necessary to redistribute $\mathbf{Q1}^{ind}$ of electricity using the physical allocation of emissions, $\mathbf{Q}^{elec}$, across the economy. That is,

$$\mathbf{Q}^{ind} = \mathbf{Q1}_{i=1:n,i\neq elec}^{ind} + \mathbf{Q}^{elec}$$

Total embodied emissions with direct allocation of electricity emissions then proceeds as:

$$\mathbf{q}^{\mathrm{ind}} = \mathbf{Q}^{\mathrm{ind}}\, \widehat{\mathbf{x}}^{\,-1}$$

$$\mathbf{Q}^{\mathrm{emb}} = \mathbf{q}^{\mathrm{ind}}\left(\mathbf{I} - \mathbf{A}^{d}\right)^{-1}\widehat{\mathbf{y}}_{d}$$

Calculations of Emissions Embodied in Imports

Assuming domestic technology is similar to the overseas technology used in the production of imported goods, we calculate emissions embodied in imports as (see Lenzen, 2001, eq. 10):

$$\mathbf{Q}^{imp} = \mathbf{q}^{ind} * \left(\mathbf{I} - \mathbf{A}^{\mathrm{d}} - \mathbf{A}^{\mathrm{m}}\right)^{-1}\mathrm{A}^{\mathrm{m}}\left(\mathbf{I} - \mathbf{A}^{\mathrm{d}}\right)^{-1}\mathbf{y}_{d} + \mathbf{q}^{ind} * \left(\mathbf{I} - \mathbf{A}^{\mathrm{d}} - \mathbf{A}^{\mathrm{m}}\right)^{-1}\mathbf{y}_{\mathrm{m}}$$

where $\mathbf{A}^{\mathrm{m}}$ is the technology matrix of imports.

Calculations of Emissions Embodied in Exports

The estimation of emissions embodied in exports is straightforward due to the identification of exports as a destination of final demand. However, imported goods can also be subsequently exported; thus, the principle equation becomes:

$$\mathbf{Q}^{exp} = \mathbf{q}^{ind} * (\mathbf{I} - \mathbf{A}^{\mathrm{d}})^{-1}\mathbf{y}_{\mathrm{d,exp}} + \mathrm{q}^{ind} * (\mathbf{I} - \mathbf{A}^{\mathrm{d}}\mathbf{A}^{\mathrm{m}})^{-1}\mathbf{A}_{\mathrm{m}}(\mathbf{I} - \mathbf{A}^{\mathrm{d}})^{-1}\mathbf{y}_{d,exp} + \mathrm{q}^{ind} * (\mathbf{I} - \mathbf{A}^{\mathrm{d}} - \mathbf{A}^{\mathrm{m}})^{-1}\mathbf{y}_{\mathrm{m,exp}}$$

where the subsets of domestic final demand $\mathbf{y_d}$ exported is denoted $\mathbf{y_{d,exp}}$ and the subset of imported final demand $\mathbf{y_m}$ to export is denoted $\mathbf{y_{m,exp}}$.

APPENDIX 2

This appendix describes the process by which greenhouse gas emissions available with the National Greenhouse Gas Inventory (NGGI) were assigned to the industrial classification used in the input–output model (344 sectors).

Fuel Combustion

Energy Data

Whilst the NGGI offers the most complete dataset on greenhouse emissions in Australia, the source data on energy consumption from the Australian Bureau of Agricultural and Resource Economics (ABARE) can provide additional detail for specific industries. ABARE no longer publishes additional detail for mining and other energy industries, and no longer publishes fuel use by equipment type. Hence, data at this level of detail come from the late 1990s. Therefore, the final data have the relative breakdown of this highest level of detail whilst conforming in absolute terms to the level of detail of the current year data.

We created an initial estimate of energy use by input–output category. This was then optimised to account for additional data on equipment use by fuel and equipment use by industry.

The sales breakdown of each of the 28 fuels in the ABARE energy statistics to all industries is used to create an initial estimate. The sales breakdown is taken directly from the input–output tables, and where purchases of the product corresponding to each fuel are shown for each industry. The input–output data are the best available detail on the use of fuels by industry, but unlike the fuel data, are in monetary terms. The effect is that there is an implicit assumption that within each category of the ABARE energy data, all industries pay the same price for fuels. This assumption is expected to be valid for most types of energy consumption. Where a significant difference in price is expected within an ABARE category, such as for aluminium production within non-ferrous metals, additional data are sourced and applied. Further, due to the nature of the ABARE data, important energy flows were at a sufficient level of detail such that the data could be allocated directly to input–output categories, whilst less energy intensive sectors, particularly within the services sector, required more disaggregation. Thus, inaccuracies caused by disaggregation are limited.

Unpublished data on mining of mineral sands, iron ore, gold, silver, etc, and briquette manufacturing, as well as the separation of aluminium from other non-ferrous metals were made available for the 1990s, and the relative values of this data were applied in the initial estimate for subsequent years.

In addition to the direct energy consumption data, energy consumption was previously available by equipment type (17 types) and fuel (27 fuels) (Australian Bureau of Agricultural and Resource Economics, 1997) and shares of equipment type were available by industry and fuel (National Greenhouse Gas Inventory Committee, 1994). The importance of this data is highlighted for particular industries such as aluminium production, silver, lead, zinc, coal and uranium mining, mineral sands mining, and others. As a result, emission factors by industry, equipment type and fuel type were used in the estimation of greenhouse emissions by industrial sector, with the final form of the energy consumption matrix showing input–output category by equipment type by fuel use.

Transport

The ABARE data set on energy consumption aggregates all forms of road transport into the 'road transport' sector – hence the data set does not distinguish between private use of automobiles, business use of automobiles and freight. Similarly, for military purposes, all energy use within vehicular transport and air transport are aggregated into the road and air transport sectors. In order to allocate transport energy use to the end use industry, military use is first extracted (National Greenhouse Gas Inventory Committee, 2008), then the remaining fuel use is apportioned between private and business fuel use for road transport (Australian Bureau of Statistics, 2003), and directly to air transport and water transport for these transport types.

TABLE A.1. Allocation of Refrigeration and Air Conditioning (AGO pers. comm.).

2.F.1 Refrigeration and Air Conditioning Allocation		%
Div M	Government administration and defence	1.529%
Div H,P,Q	Accommodation, cultural and personal	7.325%
DIV F, G	Wholesale and retail trade	8.985%
Div K, L	Finance, insurance, property and business	1.529%
R NT	Residential (non transport)	20.750%
R T	Residential (transport)	40.087%
Div A	Agriculture, forestry, fishing	1.690%
61	Road transport	18.106%

Table A1 from the methodology workbook for energy (transport) (National Greenhouse Gas Inventory Committee, 2008), provides allocation factors for military activities across road, water and air transport. These factors are used to delineate military from other uses, directly from ABARE energy data.

The remainder of the road transport energy consumption data (once military data are excluded) is split between residential and business use by means of the Survey of Motor Vehicle Use (Australian Bureau of Statistics, 2003). Total fuel consumption by fuel and vehicle is apportioned by distance travelled by purpose and type of vehicle to give energy consumption by purpose and fuel, aggregating vehicle types for non-business travel, and converting to energy units by including energy content of fuels (Australian Bureau of Agricultural and Resource Economics, 2007). Finally, due to discordance between this estimate and the ABARE energy consumption for transport, final values are scaled to match ABARE data.

ABARE data aggregate railway passenger and freight transport services. In order to delineate passenger services, energy consumption statistics on fuel consumption in passenger and freight transport services (Apelbaum Consulting Group Pty Ltd 2007) were scaled to match aggregate ABARE data.

Fuel consumption of taxis was estimated by forecasting total distance travelled by taxis, from Australian Taxi Association data and ABS data on distance travelled by vehicles (ABS Cat no 9311). The total distance travelled by taxis was converted to energy units by using fuel consumption data on new cars, with 85% of taxis assumed to be running on liquefied petroleum gas (Australian Taxi Industry Association, 2001).

Greenhouse Gas Coefficients

Greenhouse gas emissions from fuel combustion data were calculated from the estimation of energy consumption by industry, fuel type and equipment type. This maintains the level of detail available in the energy data, including specific emission factors for each industry by fuel and equipment type. Calculated emissions are subsequently constrained by published emissions of greenhouse emissions within the NGGI. The effect of this process is that the relative breakdown by input–output category within the energy data is applied to greenhouse data.

In order to translate energy data into greenhouse emissions, we consider only CO_2 emissions according to published emission factors (Australian Greenhouse Office, 2008a). In order not to double count primary and secondary fuels, and to enable tractability of important physical flows, within solid fuels only primary fuels were included. Only minor combustion of solid secondary fuels occurs for such fuels as coke and briquettes. For liquid fuels, only secondary fuels were included, such that no emissions are associated with their raw feedstock. In this way, gross, rather than net, emissions are estimated without double counting.

In addition, non-CO_2 emissions are considered for the greenhouse gases CH_4 and N_2O. Emission factors are calculated by sector, by fuel type and by equipment type (Danish Environment Ministry, 2004) and (National Greenhouse Gas Inventory Committee, 1998a, 1998b, 1998c, 1998d). Other greenhouse gases are not directly considered due to uncertainty in emission factors. They are, however, included indirectly when included in the NGGI by the benchmarking of the greenhouse gases estimated from fuel combustion with the CO_2-equivalent greenhouse emissions of the NGGI. Non-CO_2 transport emissions are estimated from the energy data, with mobile sources of emissions from Australian Greenhouse Office (AGO) Workbook 3.1 A.5.

Scope 2 Emissions

Scope 2 emissions (emissions from the generation of purchased electricity) are estimated directly from ABARE energy consumption data, specifically for electricity use. The process used in this estimation is identical to the general fuel consumption data (allocation is undertaken per economic flows from the input–output table). Emissions are then constrained by the data on scope 2 emissions in the level of detail of the Australian New Zealand Standard Industry Classification (ANSZIC). Scope 2 emissions by industry then replace the aggregate electricity emissions.

Industrial Processes

For industrial processes, emissions from category 2.A Mineral Products of the NGGI are allocated directly to the cement and lime input–output category and to Iron and Steel semi-manufacturers for Limestone and Dolomite Use. Emissions from category 2.B Chemical Industry and 2.D,F Production of Halocarbons and Sulphur Hexafluoride are allocated to Basic Chemicals and Other Chemical Products by production value. Emissions from 2.C Metal Production are allocated directly from the NGGI to the input–output categories Iron and steel semi-manufactures, Alumina, and to the three aluminium product sectors (Aluminium, Aluminium semi-manufactures, Aluminium foil – allocated within these three sectors by production value). Emissions from 2.E,F Consumption of Halocarbons and Sulphur Hexafluoride are principally due to Refrigeration and Air Conditioning Equipment, and make up almost 3 kilotonnes of emissions. The use of refrigeration and air conditioning is common to many economic sectors, hence making allocation difficult. The AGO provided allocation to ANZSIC divisions (Table A.1) which was used as an initial breakdown to industry subgroups. Emissions were then allocated according to employment for other industries, where it was assumed that air conditioning of employee space was the major cause of emissions, and according to production value for Trade and Road transport, as these sectors are margin industries with throughput assumed to reflect the volume of refrigeration of goods driving these emissions.

Emissions from foam blowing were allocated to Other Chemical products, emissions from fire extinguishers to Fire Brigade, emissions from Solvents to Machinery and Equipment and Other Electrical to Electrical Equipment. Emissions from '2.G Other' are confidential emissions but stem from soda ash, ammonia and nitric acid production. These chemicals are used within the sectors glass products, fertiliser and chemical products, pulp and paper and water supply/sewerage. The emissions are allocated to these sectors by production value in lieu of any other information.

Agriculture

For agriculture, a number of proxy variables are needed in order to allocate NGGI categories to input–output categories. The main proxies used are land use area, production volume and heads of livestock. The principal source data is the ABARE Commodity Statistics, along with ABS publication *Agricultural Commodities, ABS Cat. No. 7121.0.* Whilst data are available on total pasture land area, and land area of crops, land area data are not available for livestock. Hence, an estimation process is employed following George Wilkenfeld & Associates Pty Ltd and Energy Strategies (2002) where total natural and sown pasture area is allocated by head number, with a stocking ratio for sheep to cattle of 14.3 used (Table A.2). In addition, dairy cattle are delineated, with a stocking ratio for dairy to beef cattle of 2.

Other land area data (e.g. for crops) and production volume (tonnes) are taken direct from ABARE Commodity Statistics and *Agricultural Commodities, ABS Cat. No. 7121.0.* In 7121.0, land area data are available by irrigated area as well as total area, corresponding to NGGI classification by irrigated and non-irrigated emissions.

Emissions from NGGI category 4.A Enteric fermentation and 4.B Manure management are provided within the NGGI by type of livestock. These emissions are hence allocated directly. Emissions from 4.C Rice cultivation are also allocated directly. Within NGGI category 4.D Agricultural Soils, Direct Soil Emissions; Synthetic fertilisers are allocated directly to discrete categories and by shares in fertiliser use (see Table A.3) for non-

TABLE A.2. Estimation of land use data for principal livestock.

	Equiv Head[a] ('000)	Hectare[b] ('000 ha)	Grazing Density[c] (ha/head)	Land Share (%)
Sheep and lambs	106,166	103,691	1.0	22%
Beef cattle	24,739	345,516	1 4.0	73%
Dairy cattle	3,131	21,865	7.0	5%
TOTAL	134,035	471,071		
Pastures and grasses		471,071		
Sown[d]		24,064		
Natural[d]		447,007		

[a] ABARE Commodity Statistics 2007.

[b] Estimated from Total Pastures and Head numbers.

[c] Grazing density ratio of 14.3 used from Wilkenfield, 2002, Table 5.10.

Dairy assumed to have a grazing density twice that of beef.

[d] ABS 7121.0; 2001-02.

TABLE A.3. Allocation of emissions from synthetic fertilisers.

Synthetic fertiliser allocation	Application rates[a] (kg N_20/ha)	Land area ('000 ha)	Estimated emissions ('000 kg N_20)	Fertiliser emissions share (%)
Oats, sorghum and other cereal grains[b]	0.72	2,099	1,511	10%
Wheat[b]	0.72	11,529	8,301	57%
Barley[b]	0.72	3,707	2,669	18%
Rice	0.73	144	105	1%
Oilseeds	0.62	1,881	1,166	8%
Legumes	0.38	2,086	793	5%

[a] George Wilkenfield & Associates Pty Ltd and Energy Strategies (2002), Table 5.4, 1999 data.
[b] Application rates of cereals used.

discrete categories. The shares in fertiliser use is estimated as per George Wilkenfeld & Associates Pty Ltd and Energy Strategies (2002) and updated to current year land area data.

Emissions from Synthetic Fertilisers for Pasture are estimated solely by land area. NGGI level 5 data, Animal Waste Applied to Soils, Nitrogen Fixing Crops, Cultivation of Histosols, and Crop Residue are allocated directly to input output categories. Crop residue data for Cereals was allocated to input–output sub-categories by production volume (tonne).

Emissions from NGGI 4.D Agricultural Soils; Animal production are aggregated but are due to nitrogen excretion via faeces and urine, and are hence allocated by animal production volume (tonnes). Indirect emissions from Atmospheric deposition from fertilisers are allocated as per Table A.3. Manure is allocated directly according to identified livestock types. Emissions from Field burning of agricultural residue are again allocated by production volume (tonne) for Cereals, and directly for other categories. Prescribed burning of Savannahs was fully allocated to beef cattle grazing, as per George Wilkenfeld & Associates Pty Ltd and Energy Strategies (2002).

Indirect emissions from Nitrogen leaching and run-off were allocated per fertiliser use (Table A.3) for crops and by land use area for pasture. Emissions associated with nitrogen leaching from manure were allocated directly to respective livestock industries. Other (Soil disturbance) emissions within Agricultural Soils were allocated by land use area for crops and pasture respectively.

NGGI category 4.E Prescribed burning of savannahs was allocated fully to beef cattle, as per George Wilkenfeld & Associates Pty Ltd and Energy Strategies (2002). Category 4.F emissions from field burning of agricultural residues were allocated by land use area for cereals, and directly for pulses and sugar cane.

Land Use Change and Forestry

Land use change and forestry is broken down within the NGGI to Afforestation and reforestation and Land use change (cropland/grassland). Afforestation and reforestation emissions were allocated according to number of seedlings planted. The ABS publication

TABLE A.4. Proportion of forestry activities by purpose by area (ha) and number of seedlings planted.

	ha	no
Timber or pulp production	9%	21%
Nature conservation	15%	17%
Enhanced production (e.g. shade, windbreaks, etc)	29%	17%
Fodder and plant products	3%	7%
Protection of land and water	39%	33%
Other plantings	3%	5%

Agricultural Commodities ABS Cat. No. 7121.0 details forestry activities by purpose for both number of seedlings planted and area (Table A.4). Number of seedlings planted was used as the proxy to allocate emissions in order not to subject the allocation to difference within planting practices (intensive verses extensive planting). As a result, this does not take into account differences in seedling mortality between purposes, and assumes uniform carbon absorption by seedling. Timber or pulp planting was allocated between softwoods and hardwoods by production volume (m^3) of each. Proportion of seedlings planted for nature conservation and protection of land and water were allocated directly to Residents. Enhanced production and Fodder, plant products were allocated to agricultural sectors by land use area.

Land use change emissions from deforestation (land converted to cropland) were allocated to the various crops sectors by land use area. Emissions from land converted to grassland were allocated as per George Wilkenfeld & Associates Pty Ltd and Energy Strategies (2002), which allocated 85% of total land use change emissions to beef, 4.5% to residential, and the remainder to crops – which are separately identified in the current NGGI.

Waste

Emissions from waste are dominated by solid waste disposal on land, which are directly allocated to the Sanitary and Garbage disposal input–output sector. Emissions from wastewater handling for Industrial wastewater is allocated according to the AGO ANZSIC allocation (Table A.5) distributed to input–output categories by production value. Domestic and commercial wastewater emissions were allocated directly to the water supply and sewerage sector.

Emissions from Waste incineration for solvents were allocated to Iron and steel semi-manufacturers as per the AGO ANZSIC allocation, and other non-specified emissions were allocated to the Sanitary and garbage disposal sectors.

TABLE A.5. Allocation of emissions from industrial wastewater.

6.B.1 Waste, Wastewater Handling, Industrial Wastewater	
Wood, paper and printing	19.92%
Basic chemical manufacturing	6.43%
Food, beverages, tobacco manufacturing	73.65%