WASTE FLOWS IN THE AUSTRALIAN ECONOMY

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SUMMARY

Recently we have seen strong pressure from government instrumentalities to reduce the flow of solid waste disposed of to landfill. The reasons usually given to justify spending effort and money on this are: (1) suitable waste disposal sites are becoming difficult to find; (2) reducing solid waste flows will save resources; (3) reducing solid waste flows will reduce pollution of our environment. Although these propositions are not always true, they are seldom questioned, in part because the flows of wastes and pollutants are not available in a suitable form to permit them to be tested. The aim of the research reported here was to provide the knowledge about waste flows needed for the formulation of constructive policy on waste disposal.

The method used was to break up the Australian economy into suitable sectors and establish the flows of solid, liquid and gaseous wastes from each sector. The sectors chosen were: mining; farming; forestry and forest products; electricity, gas and water; chemicals, oil and coal products; basic metals; other manufacturing; construction and demolition; transport; commercial; and municipal. Flows of energy, water and other resources into each of the above sectors were also established. This also enabled us to gain some feeling as to whether reducing solid waste flows would reduce air and water pollution.

We established that in 1990–91, the year we examined, four and a half billion tonnes of wastes were produced in the Australian economy, two billion tonnes of both solid and liquid wastes and half a billion tonnes of gaseous wastes. Most of the flow of solid wastes is generated in the mining sector. Solid wastes from the construction, commercial and municipal sectors, which together make up the flow to conventional landfills, constitute only 1 per cent of the total solid waste flow. By far the greatest part of the liquid wastes are sewage from the commercial and municipal sectors.

Although reducing the flow of solid wastes to landfill would certainly relieve the pressures on landfills and reduce the environmental problems caused by them, the effect on the total flow of solids to waste would be negligible. Reducing the flow of wastes to landfill could reduce the generation of air pollution, especially if it resulted in less fuel being burnt. However, the effect on water pollution is likely to be negligible. Careful analysis is required before money and effort is spent on programs to reduce the flow of solid wastes to landfill in preference to other resource conservation or pollution prevention programs.

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INTRODUCTION

Background

Over the last few years pressure has been developing in Australia, as elsewhere, to reduce the flows of wastes, especially solid wastes. This has been reflected in government laws and regulations, and in education campaigns aimed at waste reduction, for example by encouraging recycling. The usual justifications given for this activity are: that sites for disposing of solid wastes are becoming scarcer and more expensive to access; that reducing the flow of solid wastes will reduce the consumption of resources used for making goods, thus conserving resources; and that using fewer resources will reduce the emission of gaseous and liquid pollutants.

These three propositions are not as straightforward as they might seem. They are, nevertheless, rarely questioned, partly because the flows of materials, including wastes and pollutants, are not expressed in a form that permits them to be tested. As a result, policy making tends to go on uninformed by any analysis, and is instead driven by an untested belief in the veracity of the above propositions.

The residential contribution to the municipal solid waste stream has been analysed in some detail, and receives the greater part of the attention of advocates of recycling and other strategies for waste reduction. However, it is only one of many wastes that may have implications for the consumption of resources and the generation of pollution. Other waste streams may be quantitatively far larger, and may give rise to far greater environmental damage. One of the results of this is that as a society we may well be putting in great effort where it can achieve very little, while ignoring other areas where much less effort would achieve far more. The first step towards a more rational approach, therefore, must be to discover the patterns of generation of wastes and pollutants and of the associated consumption of resources.

Aim

The aim of the research reported in this paper was to produce a 'snapshot' of the operation of the various sectors of the Australian economy in terms of the generation of wastes and the associated consumption of resources, including energy resources, and the emission of pollutants. Particular attention was given to the problem of establishing the relative importance of solid municipal wastes, which are the target of most waste reduction regulations and campaigns.

Perceptions of the relative importance of particular wastes differ widely, depending on a person's viewpoint and, usually, on the proximity of the waste generation and/or storage sites to the person's home or place of work. We excluded these considerations from our study by confining it to examination of quantities of wastes, and deliberately avoided taking account of where the wastes were generated or disposed of.

We calculated the flows of materials using the best sources of data we could find, but we had to make many simplifying and generalizing assumptions. However, we do not believe that this in any way invalidates the general thrust of our findings. Had we had more time available for our research, in some cases we could have replaced assumptions and approximations with hard data, and thus improved the accuracy of the results. We would appreciate hearing from readers more familiar with particular industries than we are and who have access to better sources of data.

Research approach

Our snapshot of the operation of the Australian economy was based on the year 1990–91, as this was the most recent year for which reasonably full data sets on economic activity in Australia were available. Occasionally we had to use data for earlier years, and factor in expected changes for 1990–91.

To achieve our aim, first we broke the economy down into manageable sectors and sub-sectors for which reasonable values for average generation of wastes and consumptions of resources could be assigned. We then estimated the quantities of various resources used in each sector in 1990–91, and the quantities of pollutants and wastes generated. We included gaseous and liquid wastes as well as solid wastes, so that environmental impacts in addition to the consumption of landfill sites could be considered.

We used a spread-sheet approach to perform the calculations. We consolidated the various resource streams and waste streams to show the flows of particular streams for each sector—for example, consumption of energy, consumption of water, generation of carbon dioxide, generation of solid wastes. We then displayed the results in a way that showed the relative contribution of particular sectors or sub-sectors to particular streams.

METHOD

Selection of sectors to be considered

The sectors we considered were: mining; farming; forestry and forest products; electricity, gas and water; chemicals, oil and coal products; basic metals; other manufacturing; construction and demolition; transport; commercial; and municipal. These generally follow the ASIC divisions.[1] The main exceptions are that we broke the ASIC agriculture and forestry division into two sectors and the manufacturing division into three sectors. We also used a municipal sector rather than the ASIC residential division.

In our spreadsheets we broke these down to enable us to show the contributions of major sub-sectors. In most cases, these were the sub-sectors with the greatest mass flow of products. However, in some cases it was necessary to consider other sub-sectors, because our aim was to identify sub-sectors with particularly large resource implications or pollution potential. For example, the mass of gold mined each year is far smaller than that of many other metals and minerals, but we included it in our spreadsheet because a very large quantity of solid wastes is generated in the course of producing this small amount of gold.

Mining

Reference to the ABARE *Commodity Statistical Bulletin*[2] and interviews with experts from the mining industry indicated that in Australia the metals most important in the generation of wastes are iron, aluminium, copper, the silver/ lead/ zinc group and gold. The energy minerals we considered were oil, gas, coal and uranium.[3] We also included the non-metal minerals stone, gravel, sand, gypsum, limestone, salt, silica and clay, which are mined in surprisingly large quantities. Where major beneficiating occurred close to the mine site, we counted the wastes from this beneficiating activity as being generated in the mining sector.

Farming

The sub-sectors we considered were: broad-area crops such as grains, sugar and cotton; orchards; and dairying and animal raising, including intensive animal raising.

Forestry and forest products

We considered the following sub-sectors: logging; sawlog production; wood-based products other than paper; and pulpwood production.[4] Paper production was included as part of the *Other manufacturing* sector.

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1 ASIC stands for Australian Standard Industrial Classification.

2 Australian Bureau of Agricultural and Resource Economics (ABARE), *Commodity Statistical Bulletin, 1992,* ABARE, Canberra

3 ABARE, *Energy Demand and Supply Projections, Australia, 1992–93 to 2004–05,* .ABARE, Canberra.

4 ABARE, *Quarterly Forest Products Statistics,* March Quarter 1993, ABARE, Canberra.

Electricity, gas and water

This sector was dominated by the electricity generation industry.

Manufacturing

We broke manufacturing down into three sectors so that we could get some feeling for which parts contributed most to the various waste streams. We did this on the basis of energy consumption, as this is probably the best indicator of resource use and pollution potential.[5] This approach identified two sectors for special attention: *Chemicals, oil and coal products*; and primary metal production (hereafter called *Basic metals*). All other manufacturing industries, which included things such as food processing, paper and textiles, were lumped together in a sector that we called *Other manufacturing*.

Construction and demolition

This sector included construction and demolition of structures. We also looked at the construction and resurfacing of roads and other pavements, but data for these were difficult to find. (Waste from these activities registers as engineering waste in municipal waste surveys.[6] However, an unknown amount of such waste is disposed of as 'clean fill', in both public and private land reclamation projects.)

Commercial and municipal

The *Commercial* sector included services such as health services and education. Because of the ways that waste collecting authorities do their accounting, we used the *Municipal* sector instead of the ASIC residential division.[7] This municipal sector was the same as the ASIC residential division, but included also the waste from municipal parks and streets.

Transport

This sector included road, rail, air and water transport.

Selection of waste streams to be considered

As noted earlier, we wished to examine not only solid wastes, but also liquid and gaseous wastes, because of the perception that reducing the flow of solid wastes would also reduce

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5 The ABARE *Energy Demand and Supply Projections* were used for this purpose.

6 See K. Dick, *The Composition and Origin of Solid Wastes in Sydney*, 1993.

7 See Dick, *The Composition and Origin of Solid Wastes in Sydney*.

other forms of pollution. Following this reasoning, materials were selected for examination not only on the basis of the tonnage of wastes produced, but also on the basis of their recognized potential to result in pollution, which we define here as the presence of materials in air, water and land at concentrations high enough to be harmful to health of people or other organisms, or to cause damage to property.

We confined our examination to the emission of the following in air waste streams: carbon dioxide, methane and nitrous oxide, because of their potential greenhouse effect; and the acid gases sulphur and nitrogen oxides, because of their harmful effects on humans, animals and vegetation. Other air pollutants such as airborne dust, volatile hydrocarbons and chlorofluorocarbons were not examined quantitatively.

A full examination of liquid waste streams would include: nutrients such as nitrogen and phosphorus, suspended solids, total dissolved solids; heavy metals and pesticides.[8] As such an examination would have required major additions to our study, we confined our quantitative assessment of liquid wastes to examination of their mass flows.

As solids can be immobilized far more easily than air and water, potential pollutants in solid wastes will not result in actual pollution unless management of the waste disposal process is inadequate. Therefore, in this paper our examination of solid wastes focussed principally on their mass flow, which can readily be interpreted in terms of pressure on available disposal sites.

Structure of the spreadsheet

We recorded raw data in an Excel 5 spreadsheet. Formulae were then built into the spreadsheet to calculate waste generation rates from these raw data, and qualifying comments and references to the data sources were inserted. We kept calculations of resources used and wastes generated separate for each economic sector. As some inter-sector comparisons were envisaged, we also included a consolidated cross-sector table presenting waste production and resource consumption data.

Excel 5 spreadsheets are composed of worksheets bound together. We designated one worksheet for each of the main economic sectors identified earlier, and established the cross-sector table on another worksheet. The cross-sector table posted the quantities of solid, liquid and gaseous wastes produced, in addition to greenhouse emissions and energy and water

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8 G. T. Miller, *Living in the Environment*, 6th edn, 1990, Wadsworth Publishing Company, Belmont, California.

consumption. The posted values were obtained through automatically updated linkages to each of the worksheets dealing with the economic sectors.

Spreadsheet calculations require the location of the relevant worksheet cells to be specified. Insertion or deletion of cells, lines or rows can change the spreadsheet 'landscape' without updating the cell references of calculation formulae. As this could cause gross errors, the designers of Excel 5 have included features to minimize the possibility of formulae being corrupted in this way. Nevertheless, our experience indicated that some errors of this type would inevitably occur. To ensure that any such errors would be detected, we placed a strong emphasis on orderliness within worksheets. Each economic-sector worksheet was surmounted by a table that summarized the sector's waste production and resource consumption. This table drew on details stored or calculated in tables located elsewhere on the worksheet, or on other worksheets. For example, the table summarizing the transport sector drew information from tables containing information about each transport category, e.g. road, rail, air and water.

The data hierarchy was quite extensive on some worksheets, particularly when data were very site or region-specific. For example, the data hierarchy on the mining sector featured the following:

- a summary table;
- a table of ore, mineral and metal production;
- a table presenting waste generation factors (in terms of waste generation per quantity of ore mined or processed) for the different waste types (overburden, tailings) for each major mineral. For each mineral and waste type, quantities of waste were tabulated along with the production from each mine with a significant production so that the waste generation factors could be calculated.

Additional worksheets were used to store supporting information. The economic-sector worksheets were cross-referenced to these information worksheets as required. Information worksheets prepared included tabulations of:

- annual fuel consumptions for each sector and sub-sector;
- greenhouse gas factors per unit of energy for the various fuels consumed in Australia;
- greenhouse gas emissions for each sector.

RESULTS

The detailed spreadsheet calculations and results are given in the attached appendix. The results are summarized below.

Production of wastes

Table 1 summarizes our findings on the production of wastes by sector in solid,[9] liquid[10] and gaseous form.[11]

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9 The principal sources of data for solid wastes were: **Mining**: J. I. Woodstock and J. K. Hamilton (eds), *The Sir Maurice Mawby Memorial Volume*, 2nd edn, Vols 1 and 2, Monograph No. 19, The Australasian Institute of Mining and Metallurgy, 1993; **Farming**: G. A. Stewart, 'Agricultural residues as potential fuels', in *Production of Energy from Crop and Forest Residues*, CSIRO, 1981, pp. 17—22; R. C. Loehr, *Pollution Control from Agriculture*, Academic Press, Orlando, 1984; D. H. Vanderholm, *Agricultural Waste Management Manual*, New Zealand Agricultural Engineering Institute, Lincoln College, Canterbury, NZ, 1984; M. R. Overcash, F. J. Humanik, and R. J. Miner, *Livestock Waste Management*, Vol. 1, CRC Inc., Boca Raton, 1983; **Forestry and forest products**: ABARE, *Quarterly Forest Products Statistics;* H. Moazzem, S. Leng and N. Samuel, *Long Term Consumption Projections for Forest Products—Implications for Trade and Sector Development*, Discussion Paper No. 89.6, AGPS, Canberra, 1989; I. Kennedy, 'Availability of some wood wastes in Victoria—Some economic considerations', in *Production of Energy from Crop and Forest Residues*, CSIRO, 1981, pp. 170–80; **Electricity**: J. Beretka and D. Whitfield, *Survey of Industrial Process Wastes and Byproducts Generated in Australia*, CSIRO and University of West Sydney, Macarthur, 1993; **Chemicals, oil and coal products**: Plastics and Chemical Industries Association (PACIA), *Reducing Waste*, PACIA, Melbourne, 1993; Australian Institute of Petroleum (AIP), *Oil and Australia Statistical Review 1994*, AIP Ltd, Melbourne; Shell Refining, *Shell Geelong Refinery—Community Right to Know*, Shell Refining (Aust.) Pty Ltd, Geelong, 1995; **Basic metals**: Woodstock and Hamilton, *The Sir Maurice Mawby Memorial Volume;* Beretka and Whitfield, *Survey of Industrial Process Wastes;* **Construction and demolition, Commercial, Municipal**: K. Dick, *The Composition and Origin of Solid Waste in Sydney;* Recycling and Resource Recovery Council, *Recycling and Resource Recovery in Victoria; 1993–94*, Melbourne, 1994; Maunsell Pty. Ltd., *Additional Waste Surveys for Melbourne Metropolitan Area*, Draft B Report to Recycling and Resource Recovery Council; Department of Commerce and Trade, and the Western Australia Municipal Association, *State Recycling Blueprint*, Perth, 1993.

10 Data sources for liquid wastes were as in Note 9, together with Australian Bureau of Statistics (ABS), *Australia's Environment—Issues and Facts*, ABS Catalog No. 4140.0, 1992.

11 Gaseous wastes from combustion processes were calculated from the fuel consumption data for the various sectors given in ABARE, *Energy Demand and Supply Projections*. Gaseous wastes from non-combustion sources were mostly taken from National Greenhouse Gas Inventory Committee, *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks, and National Greenhouse Gas Inventory 1988 and 1990, Summary*, Department of the Environment Sport and Territories, Canberra, 1994. Nitrogen oxide emissions were taken from the same source, and from V. Farrington, *Air Emission Inventories (1985) for the Australian Capital Cities*, Australian Environmental Council Report No. 22, AGPS, Canberra, 1988. Sulphur oxides were mostly calculated from Farrington, *Air Emission Inventories*, and from D. G. Bullerworth and J. S. Pulsford, 'Sulphur and sulphuric acid production in Australia', in Woodstock and Hamilton (eds), *The Sir Maurice Mawby Memorial Volume*, Vol. 2.

Table 1 **Production of wastes in the various sectors of the Australian economy in 1990–91**

sector	solid waste Mt/y	liquid waste Mt/y	gaseous waste Mt/y	total waste Mt/y
mining	1662	92	10	1764
farming	367	not known	24	391
forestry & forest products	25	not known	156	181
electricity, gas & water	8	not known	131	139
chemicals, oil & coal products	<1	124	20	145
basic metals	27	109	33	169
other manufacturing	2	109	27	138
transport	2	66	73	141
construction & demolition	6*	not known	3	9
commercial	5*	208	4	217
municipal	11*	1287	15	1313
total	2110	1985	496	4591

*These three quantities make up what is usually reckoned to enter conventional landfills. The 22 Mt/y given here is somewhat higher than the figure for flow to landfills given by other workers. We have checked our methods of estimation, and believe our figure to be reliable. The discrepancy is possibly due to underestimation by other workers of amounts disposed of in rural areas, or to the disposal of material in ways other than landfill.

Source: Summary presentation of the spreadsheet

As explained in the method section, the only gaseous wastes considered were the greenhouse gases and the acid gases, sulphur and nitrogen oxides. The other appreciable components of gaseous waste streams are nitrogen and water vapor, but we did not include them in our waste streams as they are major components of normal air.[12] Liquid wastes from mining operations (chiefly mine drainage water) could be quite appreciable, but were not included because of the difficulty of obtaining reliable data. Even with these omissions, the total waste stream is nearly 5 billion tonnes per year.

We can express the figures in Table 1 as percentages of the total waste stream. Solid wastes make up 46 per cent of the total stream, liquid wastes 43 per cent and gaseous wastes 11 per cent. Mining contributes 39 per cent of all wastes, the municipal sector 28 per cent, and farming 9 per cent. No other individual sector contributes more than 5 per cent. Of course, the mass of a waste stream is not the only factor contributing to problems in its disposal, but it is an important indicator that we should not lose sight of. We consider some of the other factors in our later discussion of the results.

Solid wastes

The mining sector is by far the largest contributor to the solid waste stream, with 78 per cent of the total. Of this, 67 per cent is mine overburden and mullock, and 11 per cent beneficiation waste. Farming and forestry contribute 17 per cent. The three sectors constituting the input to traditional landfills (construction and demolition, commercial, and municipal) contribute only 1 per cent between them.

Liquid wastes

Because of the difficulty of obtaining data, we have had to omit several liquid waste streams with a high pollution potential. The mining stream includes bittern from the harvesting of salt and waste water discharges from coal washeries, but does not include mine drainage water, leachate from tailings dumps and coal washery reject dumps, or discharges from tailings ponds. The farming stream excludes saline water drainage from irrigation schemes. The electricity stream excludes cooling tower blowdown. Even so, the total liquid waste stream as shown in Table 1 is nearly as large as the solid waste stream. By far the largest contribution is from residential and commercial sewage: residential 66 per cent of the total stream, and commercial 11 per cent.

Gaseous wastes

The gaseous waste stream had the smallest mass of the three: only 496 million tonnes per year, or 11 per cent of the total. The forestry and forest products sector contributed 27 per

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12 Here we are following the convention adopted in the National Greenhouse Gas Inventory Committee's *Australian National Greenhouse Gas Inventory*.

cent of the total gaseous wastes, electricity generation another 27 per cent and transport 15 per cent.

Consumption of resources

Although our principal focus in this paper is on the pattern of generation of wastes in Australia, we examined the consumption of resources also. This examination was desirable because of the strong perception amongst those working in the field that reducing the amount of solid waste would save resources. Our economy consumes an enormous variety of resources, and we could not hope to examine them all. Therefore, our sectoral examination of resource consumption looked only at energy and water, which are by far the most important in terms of quantity, and which have strong linkages to various forms of pollution. Consumptions of these resources by the same set of sectors as used in Table 1 are shown in Table 2.[13]

To bring the energy materials to a common basis, we expressed them in terms of petajoules per year (PJ/y; 1 PJ $=10^{15}$ J). The total consumption of 3839 PJ/y shown in Table 2 is equivalent to approximately 130 Mt of fossil fuels. Because the electricity industry is both a consumer of primary energy such as coal and gas, and also a producer of electrical energy for other sectors such as manufacturing and municipal, two sets of energy consumption figures are given in Table 2, the first for primary energy such as coal, oil and gas, and the second for electricity, most of which is made from this primary energy.

The figures for liquid waste given in Table 1 are repeated here for comparison. Where the liquid waste stream is greater than the water consumption, sources of water other than metered fresh water (usually sea water) have contributed to the waste stream. For example, in the mining sector, bittern from the production of salt appears as waste, and in the transport sector ships carrying export cargoes from Australia return under ballast and discharge large amounts of foreign ballast water near the Australian coast. Where the figure for liquid waste is smaller than the figure for water consumption, some of the water stream has been lost by evaporation or evapotranspiration (from crops and trees) or to groundwater. In the chemicals, oil and coal products sector the figures are identical, because we had no independent measure of the amount of liquid waste requiring disposal, and assumed it to be equal to the known water consumption.

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13 Data for energy were taken from ABARE, *Energy Demand and Supply Projections*, and for water from ABS, *Australia's Environment—Issues and Facts*.

Table 2 **Consumption of energy and water in the various sectors of the Australian economy in 1990–91**

sector	consumption of coal, oil and gas PJ/y	consumption of electricity PJ/y	consumption of water Mt/y	liquid waste Mt/y
mining	133	36	51	92
farming	25	9	10 240	not known
forestry & forest products	36	4	not known	not known
electricity, gas & water	1496	*see note	79	not known
chemicals, oil & coal products	220	17	124	124
basic metals	393	112	129	109
other manufacturing	269	64	662	78
transport	991	7	not known	66
construction & demolition	37	<1	not known	not known
commercial	52	98	349	208
municipal	187	141	2153	1287
total	3839	*488	13 787	1964

*The 488 PJ/y of electricity consumed by the various sectors is the net electricity output of the electricity generating industry.

Source: Summary presentation of the spreadsheet

Energy

By far the two largest consumers of primary energy such as coal, oil and gas are the electricity generation industry, which used 40 per cent of the total, and transport, which used 26 per cent. However, we will get a better measure of the consumption of energy by the various sectors if we apportion out the primary energy used to make the electricity over the sectors that consume it. In this way, the sectors that use large amounts of electricity, such as basic metals (largely from aluminium smelting), commercial and residential, will be debited with appropriate amounts of primary energy. When we do this, we find that manufacturing uses 38 per cent of the total primary energy (half of which is used by basic metals), transport 26 per cent, and commercial and residential 25 per cent between them. The remaining sectors use only 11 per cent of the total primary energy.

Water

Water consumption is dominated by the farming sector, which uses 74 per cent of the water. The residential sector uses another 16 per cent, and all the other sectors use only 10 per cent between them. However, most of the water going to the farming sector is for irrigation of crops and pastures, and very little ends up in the waste stream. Also, not much more than half of the water going to the municipal sector ends up in the waste stream. Thus, in the sectors using the most water the liquid waste streams are far from being quantitatively related to the water consumptions.

Minerals and forest products

Data for the consumption of other resources by sector are hard to find. However, these materials do find their way into the economy in the form of manufactured goods, and in the course of time may be expected to find their way into the waste streams. Therefore, their total consumption is of interest. Here we are not interested in the *production* of these materials in Australia, from which we might make some deductions as to the generation of wastes in the production process. (These wastes have already been shown in Table 1.) Rather, we are interested in the *consumption* of these materials in Australia, which we might expect to be connected with the ultimate disposal to waste of goods made from them.

Table 3 lists the sixteen most important mineral and forestry commodities in order of tonnage consumed.[14] (Note that in comparative terms quantities are quite small once we pass the two principal metals, steel and aluminium.)

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14 These data are taken from ABARE, *Commodity Statistical Bulletin.* We are using the word *commodity* in the same sense as ABARE does in the bulletin, to refer to resources transformed by upgrading processes into bulk materials used in manufacturing processes.

Table 3 Consumption of various commodities by tonnage in the Australian economy in 1990–91

material	consumption	
	Mt/y	% of total
crushed & broken stone	77	47
sand	34	21
limestone	14	8
gravel	12	7
clay	8	5
steel	5	3
sawn timber	4	2
silica	3	2
wood pulp & paper	2	1
gypsum	2	1
phosphate rock	2	2
salt	0.7	0.4
plastics	0.7	0.4
aluminium	0.35	0.2
zinc	0.07	<0.1
lead	0.06	<0.1
total	165	100

Source: Mining and forestry sheets from the spreadsheets

Limestone (the main constituent of cement), crushed stone and sand together supply our concrete. These three make up 76 per cent of the total. Other construction material (gravel, clay for bricks, gypsum for plaster, and timber) make up another 16 per cent, metals 3 per cent, paper and plastics 2 per cent, and silica (for glass) 2 per cent.

Production of pollutants

Table 4 shows the production of gaseous pollutants by sector. The greenhouse pollutants were calculated by adding the emissions from fuel combustion as calculated from the ABARE *Energy Demand and Supply Projections*[15] and the emissions from non-combustion sources

15 ABARE, *Energy Demand and Supply Projections.*

from the *National Greenhouse Inventory*.[16] This method was adopted because the inventory does not break down the combustion emissions by the same sectors that we used.[17] Actual emissions were then converted to carbon dioxide equivalents using the method of calculation given in the *Australian National Greenhouse Inventory*.[18] To do this, the methane emissions from the various sectors were multiplied by 21 and the nitrous oxide emissions by 290 to express their contribution to the greenhouse effect relative to that of carbon dioxide, and then added to the carbon dioxide emissions. In the table the greenhouse equivalents from the anaerobic decomposition of putrescible materials in landfills have been included in the commercial and municipal sectors.

16 National Greenhouse Gas Inventory Committee, *Australian National Greenhouse Gas Inventory*.

17 Our *total* greenhouse gas emissions are within 2% of the total given in the *National Greenhouse Inventory*.

18 National Greenhouse Gas Inventory Committee, *Australian National Greenhouse Gas Inventory*.

Table 4 **Production of gaseous pollutants in the various sectors of the Australian economy in 1990–91**

sector	greenhouse gas emissions		sulphur and nitrogen oxides	
	Mt CO_2 equivs/y	% of total	Mt/y	% of total
mining	50	8	0.02	<1
farming	71	12	0.58	19
forestry & forest products	160	26	0.01	<1
electricity, gas & water	131	21	0.27	9
chemicals, oil & coal products	20	3	0.05	2
basic metals	31	5	1.82	60
other manufacturing	29	5	0.06	2
transport	73	12	0.20	7
construction & demolition	3	<1	0.01	<1
commercial	12	2	0.01	<1
municipal	32	5	0.01	<1
total	612	100	3.04	100

Source: Summary sheet of spreadsheets

Most greenhouse gases are in the form of carbon dioxide. However, appreciable quantities of methane and nitrous oxide are also produced: methane as fugitive emissions from the mining and distribution of fuels, from farming (mostly from anaerobic digestion of cellulose in animals), and from anaerobic digestion of putrescible wastes in landfills; and nitrous oxide from soils disturbed during farming. As their greenhouse warming potential is much higher than that of carbon dioxide, they can have quite an effect. According to the National Greenhouse Inventory, 23 per cent of the total effect is due to methane, and 3 per cent to nitrous oxide.

The emission of acid gases is dominated by the basic metals sector, with 60 per cent of the total. This material is largely sulphur oxides from the smelting of sulphide ores. Another 19 per cent is generated in the farming sector, mostly nitrogen oxides from disturbance of the soil. Despite the bad reputation of the electricity, transport and chemical sectors in the eyes of the public as emitters of pollutants, these three sectors produce only a small part of the acid gases: electricity generation 9 per cent; transport 7 per cent, and the chemical and oil industry 2 per cent.

DISCUSSION

Before we go on to discuss the implications of these results, it is useful to put forward a model that we have developed that describes the generation of wastes in the economy. In this model, resources such as iron ore or trees are drawn into the economy from the natural environment via the sectors that we earlier identified as mining, farming and forestry, usually called primary industry. The outputs of these processes are commodities and, of course, wastes. The commodities are bulk materials of specified quality, such as pig iron or wood pulp. These in turn provide the input to the manufacturing sector, which we earlier divided into three sub-sectors: chemicals, oil and coal products; basic metals; and other manufacturing. The outputs of the manufacturing processes are finished goods such as food, paper, textiles and machinery, together with more wastes. The goods may be consumer goods used almost immediately, or they may have a life of many years, but in both cases they will eventually end up as wastes that have to be disposed of.

This model of the economy is shown in Figure 1. Looked at from this perspective, the economy looks like a device for converting resources into wastes in three easy stages! Of course, its real function is to provide all the services we desire as human beings to lead healthy and happy lives; the production of wastes, which we are dealing with in this paper, is an incidental outcome.

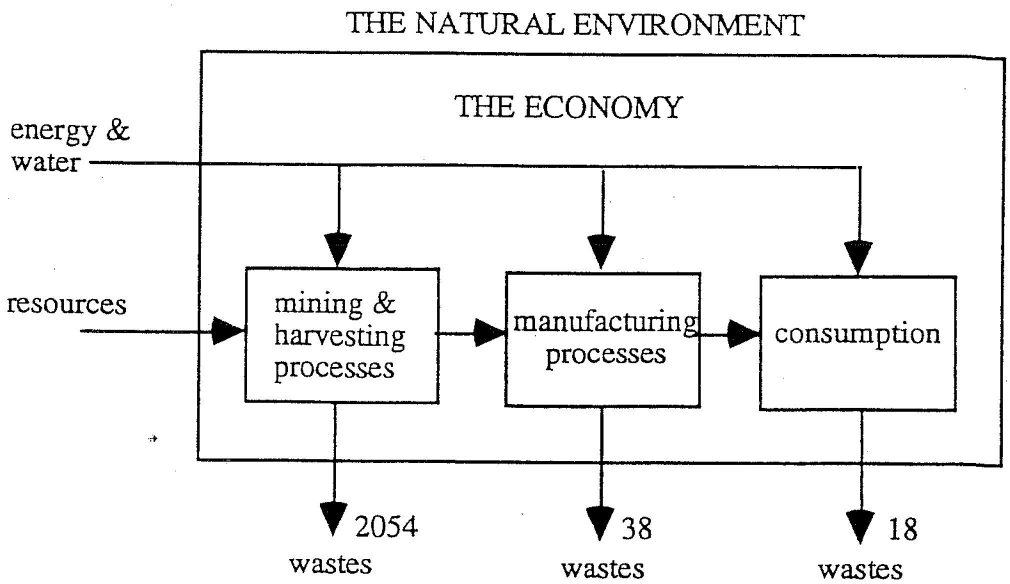

Figure 1 **A model of waste generation and disposal in the economy**
The figures against the waste flows are the flows of solid wastes in the Australian economy in Mt/y, as shown in Table 1.

Although the figures in Mt/y given against the waste flows in Figure 1 are only for solid wastes, we can have solid, liquid or gaseous waste flows from any or all of the three stages in the model. However, the origins of the types of streams are generally different. Most of the liquid streams appear because of the use of water as a carrying, washing or cooling medium. Gaseous streams can also arise from the use of air as a carrying medium, but more frequently they are the gaseous products of combustion of fuels. Because of their different origins and functions, the energy and water flows from the natural environment into the economy are shown as separate from the resource flows. They facilitate the production of the goods for consumption, but usually the goods are not produced from them (an exception is the use of hydrocarbons to form petrochemicals such as plastics.)

The resource is what is worked on by the energy and water streams to produce the goods that are finally desired. Such resources are generally solids, and in the various stages solid wastes are removed from the resource, leaving the desired residue. For example, in the production of aluminium cans we start off with bauxite deposits in the ground. Overburden is removed, producing solid wastes that have to be disposed of. The bauxite is then converted into the commodity alumina, leaving red mud that has to be disposed of. The alumina is now worked on by electricity and a carbon reducing agent in the manufacturing process called aluminium smelting to produce aluminium. This aluminium is then rolled and formed into cans. The cans are filled with beverages, and sold to consumers who drink the beverage, leaving empty cans which have to be disposed of.

The result is an ever diminishing amount of solid to be disposed of. The figures given in Table 1 show that 2054 Mt of solids are disposed of in Australia in the mining, harvesting and commodification stage, but only 38 Mt in the manufacturing stage, and 24 Mt in the final consumption stage. Clearly, the first stage is the one where the greater part of the solid wastes are produced. Partly this is due to the nature of the processes involved, but in Australia an additional factor is the large amount of material exported from Australia in the form of commodities: iron ore, washed coal, alumina, and so on. Some of this is re-imported in the form of machinery, motor cars and electrical goods that will finally end up in our waste streams. However, we never see most of it again. In Australia we export 10 tonnes of commodities for every tonne of goods we import.[19]

With our model in mind, we can now examine the results of our research in terms of the three justifications usually put forward for trying to reduce the flow of solids to waste: the reduction of pressure on solid waste disposal sites; the saving of resources; and the reduction of pollution.

The pressure on solid waste disposal sites

Nearly all programs for the reduction of flows of solids to waste concentrate on landfills accepting commercial and municipal waste, and much of the construction and demolition waste. These are the wastes from the final consumption stage in our model. As we saw from Table 1, these constitute only just over 1 per cent of the total solid wastes. The reason why this is such a low proportion of the total is clear from the model. Reducing the flow of solid wastes from the consumption stage will have a negligible effect on the total problem of solid waste disposal.

Of course, it could be argued that the provision of landfills for municipal and commercial wastes, and their operation in environmentally and socially acceptable ways, is our most pressing solid waste disposal problem. But this has to be argued in terms of clearly defined and agreed social and environmental objectives. In the light of our analysis of the very large quantities involved in the first stage, such an argument may not be straightforward. How do we compare the disposal of 10 million tonnes of municipal solid waste with the disposal of 40 million tonnes of coal washery rejects, or 1400 million tonnes of mine overburden or mullock?

One interesting feature of our analysis is the composition of the flow of commodities into the manufacturing of goods. As seen from Table 3, this is dominated by commodities

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19 United Nations, *International Trade Statistics Yearbook, 1988*. UN, New York.

used in the construction sector, such as concrete, gravel, clay, steel and timber—156 million tonnes per year out of a total of 165 million. This sector is given very little attention in popular waste reduction campaigns, perhaps because construction materials take a long time to become wastes, perhaps because these wastes do not end up in our garbage bins, and are therefore 'invisible'. The wastes that do get attention are paper, glass, plastics and aluminium, which are made from only 6 million tonnes per year out of our total consumption of 165 million tonnes of commodities.

Resource implications of the disposal of solid wastes

The second argument for the reduction of the solid waste stream from the final consumption stage is that it will save resources. To take our aluminium beverage can example again, this is true in the sense that if aluminium is 'mined' from the waste stream for recycling, we will not need to mine as much bauxite from the ground to provide the next lot of beverage cans, and the resource will therefore last longer. Thus, bauxite resources will not need to be mined so fast. Similarly, we do not need as much electricity to make new cans by melting down the old ones as we need to produce the cans from bauxite. Therefore, we will save energy resources also.

There are, however, two qualifications. First, it might take more resources of other kinds to gather material for recycling than we would save by recycling. The analysis has to be done before we can be sure which way it will go. Second, in some cases, for example iron ore, bauxite and black coal, the resource is so large that we can afford to export as much of it as we can persuade other nations to buy. In these cases why would we be trying to save it? The money spent on saving it might be better spent in more socially desirable projects. Again, the analysis needs to be done.

Effect of disposal of wastes on generation of pollutants

The third argument for trying to reduce the solid waste stream from the consumption stage is that it will reduce the emission of pollutants. In part, this ties in with the second argument. For example, if a recycling scheme for aluminium cans resulted in less energy being used than if the cans were made from virgin bauxite, we would also emit less greenhouse gas, since the burning of fuels is one of the main sources of carbon dioxide.

Again there are important qualifications. First, if the waste reduction project resulted in the production of another pollutant, how would we compare the effects of one pollutant with those of another? A good example of this is the recycling of newsprint. The savings in trees (resources which certainly are *not* semi-infinite at the rate we have been using them in the past) and the savings in energy for pulping new timber are considerable. Making these savings would reduce environmental impacts. But to make the waste newsprint usable, it must be de-inked. The de-inking process involves the disposal of a salt-laden stream, which itself presents an environmental problem.

Second, the reduction in, say, greenhouse gases, by saving energy might be quite real, but trivially small compared with the effort involved. For example, we can see from Table 4 that the generation of carbon dioxide by forest clearing is greater than that from the whole of the electricity generation industry, and is five times as great as for the *Other manufacturing* sector. Far greater potential exists for reducing emissions by paying attention to forest clearing than by reducing the disposal of manufactured goods to the waste stream.

Third, the generation of acid gases is only very weakly connected to the final consumption stage in Australia. By far the largest part of this pollutant stream comes from farming and metal smelting, much of the output of which is exported rather than consumed in Australia.

Finally, we should consider the effect of solid waste reduction programs on the disposal of liquid wastes, which in many parts of Australia presents quite serious environmental problems. As we saw from Table 1, the pattern of generation of liquid wastes is dominated by sewage from the commercial and municipal sectors, which is quite independent of the disposal of solid wastes from the same sectors. Therefore, we do not expect to see any significant reduction in water pollution arising from solid waste reduction programs.

However, one could make a case for the recycling of these liquid wastes themselves, quite independent of any solid waste reduction program. Again, the reduction in pollution would have to be measured against the costs involved, to determine whether available funds might be better spent elsewhere. Quite possibly we would be better off as a nation spending any spare money we might have on reducing the flows of municipal liquid wastes rather than on reducing the flows of municipal solid wastes.

CONCLUSIONS

- Australia has to safely dispose of four and a half billion tonnes of waste per year.
- Two billion tonnes of these wastes are in the form of solids. The solid waste stream is dominated by the mining industry, which largely produces material for export. Only 22 million tonnes per year of solid wastes are disposed of to landfills.
- A further two billion tonnes per year are in the form of liquid wastes. The liquid waste stream is dominated by sewage from the commercial and municipal sectors.

- Nearly half a billion tonnes of gaseous wastes are produced per year. These contribute strongly to the potential greenhouse problem. The two largest contributors to this problem in Australia are carbon dioxide from the combustion of fuels, and carbon dioxide from the clearing of forests. Methane from the digestive systems of farm animals also makes an appreciable contribution.
- The generation of waste material arises in three main stages: mining and harvesting of raw materials and conversion of these into bulk commodities: manufacturing of goods from these bulk commodities; and final consumption of the manufactured goods. The production of solid wastes is dominated by the first stage, and the production of liquid wastes by the third stage.
- Although reducing the flow of solid wastes from the consumption stage to landfills will reduce the environmental impacts of these landfills, it will not have much effect on the total solid waste disposal problem. Careful analysis is required to determine whether available funds should be spent on reducing the flow to landfills, or whether such funds might be better spent on other waste disposal problems.
- Reducing the flow of consumer wastes to landfills is unlikely to reduce water pollution. It would reduce air pollution if it reduced the consumption of energy or the emission of methane from the landfills. Careful analysis would be required to determine whether such effects would be appreciable.
- Despite the popular belief that reducing the flow of consumer wastes to landfill will conserve resources, the saving is likely to be quite small. Far greater conservation can be achieved by other means.

APPENDIX

This Appendix contains a set of printouts from the spreadsheet referred to in the text of this report. These are arranged in the following sequence, with the number of pages in each section shown in parenthesis:

- Summary (1 page)
- * Mining (9 pages)
- Farming (13 pages)
- Electricity, Gas and Water (4 pages)
- Forestry and Forest Products (9 pages)
- Basic Metals (8 pages)
- Chemical, Petroleum and Coal Products (4 pages)
- Other Manufacturing (2 pages)
- Commercial (3 pages)
- Transport (5 pages)
- Construction (3 pages)
- Municipal (9 pages)
- Gas and Energy Factors (5 pages)
- Energy Consumption (8 pages)
- Greenhouse Calculations (8 pages)
- Pollutant Gases (2 pages)
- Acid Gases from Fuels (13 pages)
- Other Codes (3 pages)

These sections contain the tabulated data used to generate the information presented in the report, together with details of assumptions made, data sources and other relevant comments. In the instance marked * an abridged form of the printout is provided here. A copy of the unabridged printout (39 pages) for this section has been lodged with the Association of Liquidpaperboard Carton Manufacturers Inc. Copies are also available from the authors.

It should be noted that large Tables from the spreadsheet have had to be spread over several pages in this Appendix. This should be taken into account when studying the attached material.