# THE DEMATERIALIZATION POTENTIAL OF THE AUSTRALIAN ECONOMY

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# The Dematerialization Potential of the Australian Economy

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ABSTRACT

*In this paper we test the long term dematerialization potential for Australia in terms of materials, energy, and water use as well as $CO_2$ emissions, by introducing concrete targets for major sectors.*

*Major improvements in the construction and housing, transport and mobility, and food and nutrition sectors in the Australian economy, if coupled with significant reductions in the resource export sectors, would substantially improve the current material, energy and emission intensive pattern of Australia's production and consumption system. Using the Australian Stocks and Flows framework we model all system interactions to understand the contributions of large scale changes in technology, infrastructure and lifestyle to decoupling the economy from the environment. The modelling shows a considerable reduction in natural resource use, while energy and water use decrease to a much lesser extent because a reduction in natural resource consumption creates a trade-off in energy use. It also shows that trade and economic growth may continue, but at a reduced rate compared with a business-as-usual scenario. The findings of our modelling are discussed in light of the large body of literature on dematerialization, eco-efficiency and rebound effects that may occur when efficiency is increased. We argue that Australia cannot rely on incremental efficiency gains but has to undergo a sustainability transition to achieve a low carbon future to keep in line with the international effort to avoid climate change and resource use conflicts. We touch upon the institutional changes that would be required to guide a sustainability transition in the Australian economy, such as, for instance, an emission trading scheme.*

Keywords: dematerialization, physical accounting, stocks and flows, resource productivity, material flows, Australia

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## INTRODUCTION

The dynamic and self-regulation of industrial development can be illustrated with a simple systems model describing the interrelationship between quality of life; wealth and natural resource use (see Fischer-Kowalski, 1997). In modern industrial society, these three components are positively linked. Therefore, industrial societies – within certain limits - experience positive feedbacks between their economic development, the amount of natural resources used and emissions and quality of life. Additionally, each of these components may have an internal growth dynamic.

Whether such self-reinforcing growth can occur indefinitely or only until certain constraints or limits hinder further growth is a key question facing environmental policy. Thermodynamic considerations suggest that eventual scarcity of important resources (fossil fuels and metals) will occur and the potential of natural systems to absorb waste and emissions will decrease, thus curbing further economic activities.

Within the environmental policy discourse of the last four decades, three types of delinking were discussed. In the 1970s, a Club of Rome report (Meadows, 1972) argued that improvements in quality of life could be delinked from economic growth and that actually economic growth, above a certain income level, does not enhance quality of life. The authors argued that in a resource constrained world sustained exponential economic growth would lead to catastrophic outcomes and would not support a good life at all. The notion of steady state and zero growth attracted harsh political antagonism but ultimately even the advocates of economic growth have had to retreat by acknowledging that gross domestic product (GDP) has been used as a measure of welfare, without actually measuring welfare. As a consequence, attempts have been made to correct GDP in order to show the 'real' welfare effect in industrial economies. Most prominent amongst the attempts to calculate a green

GDP was the Index of Sustainable Economic Welfare (Cobb and Cobb, 1994; Stockhammer et al., 1997).

Another critique that emerged was about the link between quality of life and resource use. The main proponents argued that ultimately more material goods and possessions do not automatically lead to greater happiness and that in fact aspirations buoyed by the advertising industry lead to a cycle of work and spending which stresses people and households. As an example of this line of argument, Juliet Schor (1998) showed how US society has been increasingly involved in a vicious cycle of overworking and overspending, which is reinforced by the socialisation process from an early age (Schor, 2004). On a similar line for Australia see Hamilton and Denniss (2005).

As a third tack, the new public and policy discourse around sustainable development has allowed a rethinking of the delinking debate by avoiding questioning economic growth as such. The main focus of the emerging efficiency and dematerialization debate has been to avoid wasteful management of precious natural resources through inefficient use. A significant increase in the efficiency of material and energy use to produce certain goods and services would, so the argument follows, enable economic growth and an increase in quality of life alongside reductions in material and energy throughput.

The potential for increased resource efficiency has been characterised by striking slogans such as Factor 4 – doubling wealth while halving resource use (Von Weizsaecker et al., 1997) and Factor 10 (Hinterberger and Schmidt-Bleek, 1999). As many analytical studies have shown, there is great potential for efficiency gains, which has been well documented in the area of energy use (Jaenicke and Weidner, 1995). The dematerialization debate has often used the argument that increased wealth eventually leads to better environmental policies and therefore reduced environmental impact, and has used the so called ‘Environmental Kuznets Curve’ to demonstrate this argument (Selden and Song, 1994; De Bruyn, 1998). While empirical examples for dematerialization can be demonstrated for emissions that may be targeted by end-of-pipe technologies, there is little evidence on dematerialization in regard to overall material and energy use. For most countries, gains in efficiency of materials and energy use were relative, and have not led to a decrease in total throughput (Weisz et al., 2006).

A significant volume of literature exists around the issue of whether or not increased efficiency leads to environmental (or social) improvements. There is substantial empirical evidence and theoretical arguments that efficiency gains, by themselves, have not generally resulted in an overall decrease of pressures, but instead are likely to have contributed to increased pressure due to the “rebound” effect also known as “take-back” or Jevons paradox (Polimeni and Polimeni, 2006; Huesemann, 2003; Herring, 2006; Homer-Dixon, 2006) and a special issue of Energy Policy (Schipper, 2000).

Historical research has shown that for many industrial economies carbon intensity has been continuously decreasing for well over a century (Grübler, 1998, Ayres et al., forthcoming). At the same time, overall carbon emissions have grown exponentially (Grübler, 1998). There is debate whether efficiency gains have enabled overall growth or whether without the efficiency gains, emissions would have been even higher because of population and economic growth eg. Laitner (2000). An alternative view takes a broader systems perspective and considers potential social or economic feedbacks between production and consumption - suggesting that technological improvements have led directly or indirectly to economic growth (Homer-Dixon, 2006) and the conditions for population growth (Brookes, 2000).

Such views are given more general theoretical grounding by the work of Saunders (2000), who shows that the theoretical existence or lack of rebound depends on the production function assumed for the economy, and the magnitude of rebound is driven by the degree of substitution between factors (eg., labour, capital, energy). Of particular importance is the existence of interactions between factors of production (eg., technological improvements increasing energy efficiency and simultaneously or subsequently increasing labour productivity), which may produce strong rebound and even “backfire” i.e., where final output is greater than when no efficiency gain is made.

In this paper we present analysis of changes that include efficiency gains, but do not assume or prohibit rebound. This is achieved by using a modelling system that incorporates only the physical effects of changes to the physical processes throughout the Australian economy. These changes may involve behavioural shifts such as different consumption rates, engineering initiatives such as the introduction of productive capital, and technological progress such as efficiency gains in that capital. These exogenous changes may result in savings in any or all factors of production in the Australian economy. Subsequently, it is possible to consider what use, if anything, is made of these savings.

For example, if considerable effort and investment were to target those activities that are of main significance for overall resource use and emissions, namely transport and mobility, construction and housing, food production and nutrition (Spangenberg and Lorek, 2002) there might be a significant overall effect on absolute resource use and emissions. This is what we are testing for the Australian economy, by employing resource flow modelling for a dematerialization scenario.

Previous research (Schandl et al., 2008) shows that the Australian economy has a distinct metabolic profile. Australia's large export oriented natural resource sectors of agriculture and mining, the ways in which nutrition, water, housing, transport and mobility and energy are provided, as well as the consumption patterns of Australia's wealthy urban households, create this unique pattern. Natural resource extraction, currently at 60 tonnes per capita (year 2006), is more than twice as high as in the United States and four times that of the OECD average. Resource productivity has not improved since the 1980s and is only a third of the United States and the OECD average.

Australia is one of the major net exporters of natural resources, including goods such as coal, iron ore, copper, wheat and meat. Australia's per capita $CO_2$ emissions are among the highest in the world. Fischer-Kowalski et al. (2008) used the concept of socio-ecological regimes and metabolic profiles to cluster all countries. Australia was clustered in a group with the United States, Canada and New Zealand, which were characterised by a per capita average income which is by far the highest on the globe. At the same time, per capita levels of materials and energy use are exceptionally high as well, which is enabled by extensive resource endowment and extensive natural landscapes. There is however considerable difference between the resource use profile in the United States and in Australia with regard to the role of trade. The US organises many economic activities within its own territory whereas international trade plays a big role in Australia. Most consumer goods are imported while exports are dominated by natural resources.

This economic structure imprints on Australia's landscapes and contributes to significant environmental and social impacts.

Revenues from natural resource exports have contributed to an economic boom in Australia but have also contributed to a decline in other productive economic sectors (most notably manufacturing). Increases in the real exchange rate and wages, as well as labour shortages, have made manufacturing less competitive on the world market. Previous resource use modelling shows that Australia's future economy may further increase its resource dependency until 2030. How such an economic structure can be reconciled with attempts to transition to a low-carbon environmentally friendly economy becomes a major political challenge.

In this paper, we use our modelling capacity to empirically test the consequences of a dematerialization strategy for Australia. If policy frameworks and incentives start to change, as suggested by the Australian government strategy to introduce an emissions trading scheme (ETS), how would that change the environmental performance of the Australian economy?

We start by providing background on the methodology used for the assessment; we then describe the scenario assumptions for the dematerialization scenario; we show how material and energy use, water use, $CO_2$ emissions and employment would change if such a dematerialization strategy were implemented, and close by summarising the main findings.

## METHODOLOGY

The analysis presented in this paper is based on quantitative scenarios that were created using the Australian Stocks and Flows Framework (ASFF). The ASFF is a process-based simulation of all sectors of the Australian economy, tracking the dynamics of major capital and resource pools, and the flows associated with these stocks such as productive output, resource inputs and changes in capital (Poldy et al., 2000; Turner and Poldy, 2001; Foran and Poldy, 2004; Lennox et al., 2005). The economy and environment are simulated in physical terms—common units throughout the framework are tonnes, litres and joules. Starting with the population's needs for food, housing, transport, education, health care, etc., the model determines the domestic requirements for commodities, buildings, vehicles, infrastructure, water, materials and energy. Domestic provision of these good and services leads to further requirements for manufacturing plants, other infrastructure – and resource inputs including water, materials and energy. Primary sector modules (agriculture, forestry, fishing and mining) provide the raw materials for domestic use and export. A trade module accounts for imports and exports of primary and secondary material and energy commodities and manufactured goods.

The ASFF was calibrated over the period of 1941–1996 to reproduce many national data series of labour, trade, materials and energy use. The ASFF and related simulations have been used in studies of the environmental implications associated with future population (Foran and Poldy, 2002), agriculture (Dunlop and Turner,, 2003), fisheries (Lowe et al., 2003), climate change (Turner et al., 2007; Jones et al., 2005), human settlements (Lennox and Turner, 2005) and water-energy systems (Kenway et al., 2008).

The primary purpose of the ASFF is to explore the feasibility and implications of assumptions about the Australian economy and society. Quantitative scenarios are created with numerical values of many exogenous variables reflecting the assumptions of the scenario. Many of the exogenous variables represent choices that are made in society. The scenarios created are not predictions, but explorations of potential futures constrained by biophysical laws embodied in the ASFF. Since the ASFF does not incorporate any optimisation or equilibration routines, initial scenarios may result in undesirable or even biophysically unfeasible outcomes. Such tensions must be resolved by the analyst using the ASFF by making suitable changes to the settings of the exogenous variables after examining the various chains of cause and effect. This application of the Design Approach (Gault et al., 1987) encourages system learning and the creation of innovative solutions since assumptions about socio-economic choice are not hardwired into the ASFF. This has much in common with the key features of Structural Economics (Duchin, 1998).

In this study of the dematerialization potential of the Australian economy, two scenarios were used for comparison: a "background" scenario that represents a business as usual future for the Australian economy, and a "dematerialisation" scenario that attempts to reduce material and energy flows through the Australian economy while still maintaining economic growth. For the background scenario, we used the high immigration scenario of the Future Dilemmas report (Foran and Poldy, 2002). The scenario reproduces the past decade of increasing immigration rates and population growth, as well as a range of other physical attributes of the Australian economy.

The dematerialization scenario maintains the same population and a host of other settings of the background scenario, while making changes to parameters that described the material and energy efficiency of the high material flow sectors of the economy, as well as some key consumption or behavioural parameters. The scenario was created for a report on "green collar jobs" which examined the potential for creating jobs or skills necessary when greening the economy (Hatfield Dodds et al., 2008). The assumptions and settings for this dematerialization scenario are described in the following section. The assumptions and settings evolved over time to the final ones presented below as we examined the output of the ASFF and attempted to reduce the environmental impact while growing the Australian economy.

## DEMATERIALIZATION SCENARIO

The dematerialization scenario involves a series of policy strategies to reduce material and energy flows. The scenario is focused on the key material and emission intensive sectors: construction and housing, primary export industries, electricity generation, transport and mobility, and food production and nutrition. The settings described below were established to explore the implications of aspirational and transformational changes. These changes are implemented without incorporating any “rebound effect”, or “take-back”, where efficiencies and subsequent cost-savings can result in further economic growth and consumption. Absence of rebound is consistent with, for example, an economy operating under an imposed cap on the resource use system.

### *Construction and Housing*

Construction and renovation of residential dwellings assumes the use of solar passive concepts to achieve relatively rapid material and energy efficiency improvements. Average building energy requirements per unit floor area were halved from today’s annual average of 80 $kWh/m^2$ to an average of 40 $kWh/m^2$ in 2025, assuming for example, wide-spread use of solar hot water systems, double glazing and insulated roofing and walls. This would involve a thorough refurbishment program of the extant building stock, and the large majority of new dwellings achieving greater energy savings through optimal orientation and design. In terms of building materials the scenario assumes that new dwellings use light insulating outer structures keeping the thermal mass inside, resulting in past trends continuing over 20 years until a 50% decrease of overall mass is achieved. Building material composition has been adjusted to higher percentages of glass and wood, lower brick and concrete. Additionally, the growing trend in dwelling floor area has been reversed incrementally to approximately 150$m^2$ average dwelling size by mid-century.

*Primary Export Industries*

Primary industries also undergo a gradual transformation to a stabilised use of Australia's endowed resources in mining and agriculture. Flows of materials through international trade were diminished in the dematerialized Australian economy. Exports of livestock products were maintained at a constant level throughout the scenario.

In the mining sector, it was assumed that current mining leases are maintained and utilised for another 20 years, after which the dematerialization transformation of the economy involves a reduction in this activity. Growth in production of major minerals and energy commodities was continued at current rates, peaking at about 2030 and subsequently decreasing to contemporary production rates in 2060. This production and export profile is designed with a dematerialized economy as an objective, and is not an assumption about international demand for Australian commodities. This profile also has the benefit of being consistent with current mineral reserve and resource estimates. Despite these reserve/resource estimates being large on an international basis, the contrary case of continually compounding growth in extraction rates beyond a few decades is not assured.

*Electricity Generation*

Historically, Australia's electricity production was largely (about 80%) coal-based thermal power generation (Schandl et al., 2008). For electricity production of the dematerialization scenario, coal-based power is phased out as existing plants age, to be replaced by wind, photovoltaic and gas-powered generation in equal proportions (of electricity delivered for otherwise unmet demand). Taking account of capacity factors and existing plants the scenario assumes installed capacity of 27% gas-based power, 59% in wind capacity, and 14% photovoltaic power. The modelling assumes that the gradual transformation away from coal is virtually completed by 2050.

The technical feasibility of such a transformation to renewable energy is currently debated around the issue of whether variability of wind and solar power generation prevents their incorporation beyond about 20% into an integrated electricity network without compromising the stability of the network or power delivery (EFF, 2006). Other research suggests that the use of future energy storage systems (eg. compressed air, super capacitors, or fuel cells) and geographic dispersion of renewable generators will overcome such technical network hurdles (Saddler et al., 2004). To explore the strategic physical possibilities and implications, we have assumed the latter.

*Transport and Mobility*

Changes in urban transit implement a modal shift in commuting away from private vehicles (down from current levels of about 85% to 60% in 2050), towards the use of public transport, bicycling and walking. The efficiency of public transit in terms of passenger load is increased by about a third. Shorter commuting distances, reduced by some 30% in 2050, reflect improved urban design incorporating more distributed employment zones and improved urban mix. Growth in the share of inter-city travel by air is reversed, assuming bus and rail travel dominates (more than 70% in 2050).

*Food Production and Nutrition*

Improvements in nutrition are addressed through per capita dietary adjustments toward a higher share of fruit, vegetables and cereal-based food, and less meat, dairy, and sugar. The projections modelled are in keeping with a number of historical trends, though a 50% reduction in meat consumption represents a significant departure. We assumed that the overall annual volume of food consumed per capita falls by about 10% by 2050, i.e., back to about 1980 levels of some 1.2 tonnes per capita.

*Other Scenario Assumptions*

A large number of settings in ASFF were common between the dematerialization and background scenarios. For instance, in contrast with the material and energy parameters described above, other parameters such as the fuel efficiency of cars and stationary machinery remained unchanged between scenarios. As a rule, these efficiencies improve over time toward a saturation level before 2050, with initial rates of increase similar to recent historical trends.

Similarly, labour participation rates and intensities of labour required in all sectors were consistent between scenarios, except for services. Generally, labour productivity was maintained at a constant level equal to recent historical values throughout the simulation period. A constant setting was adopted to highlight the effects of dematerialization on employment, rather than confound the analysis with temporal variations in labour productivity. Subsequently, the participation rate of the population in the labour force was set to achieve a constant unemployment rate (4%) in the background scenario. This required participation rates which marginally reverse historical trends for males and continue a saturation trend increase for females. The same participation rate was also used in the dematerialization scenario. In order to achieve the same 4% unemployment in the dematerialization scenario, it was necessary to increase the labour intensity for some service sector employment, i.e. the number of occupational service workers per head of population.

## ENVIRONMENTAL AND OTHER OUTCOMES OF A DEMATERIALISATION STRATEGY

In this section we present a range of outcomes in environmental and economic indicators comparing the dematerialization and background (business-as-usual) scenarios. Implementing the dematerialization strategies outlined above yields significant improvements in the material, energy, $CO_2$ and water accounts of the domestic economy, when compared with a business-as-usual scenario that does not employ dematerialization actions. With regard to economic growth and employment prospects, the dematerialization scenario does not perform as well as the business-as-usual.

In the following analysis an emphasis has been placed on comparing the scenarios and changes in trends by indexing the indicators with reference to contemporary levels (i.e. indexed to 100 at 2011). In the cases where it is relevant, the time series includes the historical period from 1950, and extends to 2050 in the simulated scenarios.

### *Material Flows*

The dematerialization scenario tested with the ASFF model shows dramatic changes in physical flows when compared to the business-as-usual scenario. Figure 1 compares direct material input of all materials (i.e. domestic extraction plus imports) for both scenarios.[2]

Direct material input peaks around 2030 (giving a rate of about 65 tonnes per capita) after which the total decreases to levels some 15% above contemporary levels by 2050 in the dematerialization scenario. The success of the dematerialization scenario in turning around resource use patterns is mainly enabled by a reduction in the export of bulk mineral commodities (such as coal, iron ore, aluminium and alumina, iron and steel, while uranium and natural gas might still grow). Such change could be driven by a global introduction of emission trading. A positive contribution from the building industry is also made, although much smaller than a change in the trade of primary materials.

*FIGURE 1 ABOUT HERE*

*Energy Use and $CO_2$ Emissions*

Final energy consumption has been aggregated across all sectors of the Australian economy, including stationary energy use and transportation. Figure 2 shows that final energy consumption decreases marginally for about two decades in the dematerialization scenario, and then climbs slowly to be about 20% higher than current levels by 2050. This pattern reflects initial gains through energy efficiency (particularly in buildings) which are later outweighed by population and economic growth.

*FIGURE 2 ABOUT HERE*

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[2] The scenario in the ASFF framework uses the standard definitions for material flow accounting as outlined in Eurostat (2001).

As Figure 3 shows, the trend for $CO_2$ emissions of combustion processes is similar but not identical to that for final energy use. As the major greenhouse gas emitted in the Australian economy, $CO_2$ is presented here as a proxy for greenhouse gas (GHG) emissions. Other important gases in the Australian context include nitrous oxide and methane, with significant contributions from the agriculture sector.

*FIGURE 3 ABOUT HERE*

Despite the substantial efficiencies and energy generation changes assumed in the dematerialization scenario, such as the complete phasing out of coal-based power generation by 2050, $CO_2$ emission reductions do not meet the targets formulated by the Australian Government (Garnaut, 2008). The reason for this is evident from Figure 4 where $CO_2$ emissions have been disaggregated by sector. All sectors initially show some degree of reduction in $CO_2$ emissions. Emissions from electricity generation would be substantially reduced for about 2 decades (to about 40% of contemporary levels in 2030), and then would grow slowly. The trend displayed is a combination of the energy efficiency introduced in buildings therefore reducing demand for electricity, and the structural changes to electricity generation. Other sectors also show reductions (which are large in relative terms for primary industries and buildings). However, transport and secondary industry continue to contribute high, and growing, emissions.

*FIGURE 4 ABOUT HERE*

Growth in overall activity in almost all sectors offsets many of the gains made through improved efficiencies. This is not necessarily a result of any ‘rebound’ effect in this study. This growth is driven by a combination of population growth and consumption rates per capita, and by common assumptions between the business-as-usual and dematerialization scenarios. As a result, the capacity for reducing energy use and $CO_2$ emissions below certain levels is constrained and the ambitious changes that have been assumed for the dematerialization scenario do not achieve the aspired reductions of 60% and more. While dematerialization of the economy might well contribute to reducing energy use and $CO_2$ emissions, the political targets might be met for instance if large volumes of carbon capture and storage were assumed to be feasible and acceptable and if large contributions by purchasing international permits were considered (Hatfield Dodds et al., 2007).

*Water Use*

The large majority (about 70–80%) of Australian water use is accounted for by irrigated agriculture, with substantial portions for dairy pasture, cotton and rice. Much of the pressure on water availability occurs in southern Australia, particularly the Murray-Darling Basin, and more recently in coastal catchments associated with urban water supply for state capital cites. Water resources in the north of Australia have not been substantially developed to date.

Both the background and the dematerialization scenarios embody a large increase in water use. These projections do not take full account of potential variations in water availability due to drought or climate change, which are likely to limit water availability further. Consequently the water use projections are best interpreted as depicting potential pressure on Australian water resources. The background scenario projects water use increasing in 2050 by some 65% above contemporary levels. Dematerialization results in increasing water use that is about a third less than it would be without policy action, with decreases in water use in currently developed southern water systems (particularly irrigated pasture) and growth in water use in urban areas and Northern Australia by 2050. Some relief in water use is achieved by the move away from thermal power stations for electricity generation. Urban water use contributes increasing pressure, equalling use on irrigated pasture by 2050.

*Economic Growth in the Dematerialization Scenario*

To assess the potential impact of a dematerialization scenario on economic growth we calculated an indicative measure of GDP from the ASFF based on the physical stocks of capital and labour. This indicative GDP is an approximation for an income-based GDP (ABS, 2000). We combined the labour numbers in the ASFF with salary and wages data to calculate the 'compensation of employees' component of GDP, and to estimate the 'gross operating surplus' component the stocks of productive capital in the ASFF were combined with calibrated data on the cost of capital and an assumed rate of return upon investment of 10% for all sectors. This income-based GDP was calibrated to reproduce observed historical GDP. For the scenarios, no assumptions were made about movement in future labour salaries and price of capital or rates of return; such changes would require economic modelling or expert advice. Instead, this analysis maintained salaries and prices at a constant level, therefore indicating the effect of physical changes in the economy on the GDP, all else being equal.

Figure 5A shows that growth in GDP moderates after 2030 in the dematerialization scenario compared with the business-as-usual scenario, largely due to assumed reductions in exports of mining and agricultural commodities. Nevertheless, indicative GDP continues to grow faster than material flow and energy use, as illustrated above. Consequently, resource productivity of the dematerialization scenario is higher than contemporary values. The indicative GDP rate per head of population (GDP per capita) in Figure 5B shows that after a two-decade rise, this measure of the Australian standard of living saturates after 2030 in the dematerialization scenario.

*FIGURE 5A ABOUT HERE*

*FIGURE 5B ABOUT HERE*

We also found that the volume of international trade would differ significantly between the dematerialized and business-as-usual economies. The physical trade balance (PTB), i.e. imports minus exports expressed in trade volumes (in tonnes) is initially about 10–20% higher in the dematerialization scenario by 2030, and then increases to about 50% or more of the business-as-usual scenario by 2050. This analysis makes no judgement about the state of international trade markets and the Australian balance of trade in monetary terms, but it does indicate that these may be impacted. Such impacts are likely to affect Australian foreign exchange rates, and in turn, the volume of exported commodities and imported goods.

*Does Employment Decrease?*

There has been an ongoing debate in the literature and policy sector over whether environmental policies and a reduction in resource use and associated environmental pressures would come at the cost of employment or, on the contrary, environmental improvements would actually be a driver for new economic activities, businesses and jobs.

As shown in Figure 6A, implementing dematerialization policies maintains employment growth in manufacturing, agriculture, food, and mining and transport sectors despite achieving large improvements in material and energy efficiencies. However, employment in most of the high material flow sectors would grow more slowly than the national average, and is lower than for the business-as-usual scenario (shown in Figure 6B). Additionally, while most sectors experience net employment growth from current levels this would not be the case for heavy industry and power generation in the dematerialization scenario. The displacement of workers from high material flow sectors does not occur evenly between the sectors or over time, as the comparison between Figures 6A and 6B show.

Employment growth in the construction sector is marginally higher in the early period than in the background scenario, due to the increased labour required for retrofitting buildings for energy efficiency measures. This situation reverses after about 2020 due to the increased lifespan of buildings in the dematerialization scenario. Employment in manufacturing is stable, contrasting with observed declines from around 1970 to the 1990's. Transport shows employment growth, and although there is little difference between scenarios, compositional changes occur in the dematerialization scenario, with decreases in freight and increases in public transport.

Agricultural labour shows a slight increase in absolute numbers over the period, contrasting with the historical trend reduction. Employment in mining and energy commodities grows strongly, however, from a very low base. Employment in these primary production sectors levels off in the second half of the dematerialization scenario.

Employment in heavy industry contracts by about 20,000 jobs at 2050 due to lower throughput of basic materials and energy. This is a combined effect of changes to the structure of electricity generation and flow-on effects of reduced demand for output of heavy industry from other sectors of the economy.

*FIGURE 6A ABOUT HERE*

*FIGURE 6B ABOUT HERE*

In recent decades, the majority of Australian labour has been in the service and trade sectors and, as Figure 7 shows, national employment would grow steadily in both the dematerialization and business-as-usual scenarios. By 2050 total employment has risen 60% above current levels, with about 7.5 million additional workers employed (relative to 2006). The majority of jobs will have occurred in service and retail/wholesale trade sectors that are not directly related to high material flows. In a sense, service sector jobs have a much smaller direct environmental impact than jobs in primary industries or in manufacturing but they do reinforce growth in resource use because of high incomes, increased purchasing power of households and resulting consumption patterns.

In the dematerialization scenario, employment in the service and trade segment grows more substantially than the high material flow sectors (manufacturing, construction, agriculture, mining and transport). This occurs because workers in the high material flow sectors displaced by the changes made in the dematerialization scenario are assumed to be absorbed by the service sector. This shift was implemented to maintain unemployment at the same level as the background scenario (i.e. 4%) and to limit the stimulation of material based sectors in a dematerialized economy.

While this approach was adopted in order to compare the physical implications of the dematerialization scenario with business-as-usual, all displaced workers would not necessarily be reemployed in the service sector. The growth in the service sector we modelled was supply-driven, not demand-driven, and more research is required to confirm its validity. Without the shift to service jobs, unemployment rates would rise from a business-as-usual of 4% and would approach

5% by 2050. This level is also contingent on labour productivity remaining constant throughout the scenario. Instead, if labour productivity were to continue increasing in line with the historical trends of fewer workers per unit output, unemployment rates would be higher in the dematerialized economy, all else being equal.

*FIGURE 7 ABOUT HERE*

## INSTITUTIONAL CHANGES FOR GUIDING A DEMATERIALIZATION STRATEGY

The strategies modelled yield significant reductions in material and energy flows within the domestic economy relative to a business-as-usual scenario. However, there appears to be trade-offs between environmental performance and some economic/social indicators. Compared with a less energy and material efficient economy, some reduction in economic output, and potentially some increased unemployment, results from the dematerialization scenario. The option to grow the service sector that was assumed here could be achieved by substantial changes in the way we produce and consume, such as increasing lifespan of goods and shifts from goods to services.

The changes outlined in the dematerialization scenario are well above what can be achieved by conventional efficiency gains and incremental adjustments that would always occur in business activities. hey would require fundamental changes in incentives, infrastructure and aspirations to be enabled. The Australian Government is planning to introduce a carbon price and carbon trading system to reward innovation in energy efficiency of businesses and households (Department of Climate Change, 2008). It is assumed that permits to emit greenhouse gases would be auctioned and all revenue returned to government. Free permits would be used to insulate emissions-intensive trade-exposed industries for a certain time and all remaining revenue would be used to reduce personal and corporate income tax. Such tax reform would encourage employment due to an increased incentive to participate in the workforce and would encourage businesses to invest, resulting in capital formation. This would also result in increasing household incomes and growing productive capacity and would therefore support a rebound effect which would consume some of the efficiency gains, unless there are firm limits on the number of emission permits. At the same time, increased resource and energy efficiency alongside increased labour productivity might considerably lower the prices of many products, which would encourage higher consumption (Ayres and van den Bergh, 2005).

Previous studies have suggested that productivity gains should be rewarded in increased free time rather than income rises in order to support changes in lifestyle and consumer behaviour away from patterns of work and spending to sustainable consumption (Schor, 2004).

In a more general sense, energy generation, mobility and transport as well as housing would require dramatic improvements well beyond what was suggested in our dematerialization scenario. The objective is to invent, design and create new industrial infrastructure that uses less energy and is less dependent on a stable supply of energy that uses fewer materials and allows for higher flexibility and low risks in the face of global environmental change and resource scarcity. This requires human intelligence, creativity and participation.

## CONCLUSIONS

We used a national model to explore the potential of a dematerialization scenario for the Australian economy and the consequ ences for resource use, employment and economic growth. The ASFF model represents a technology based ‘physical economy’ approach and tracks all relevant physical stocks and flows in the Australian economy.

The dematerialization scenario developed shows that well designed policies can substantially decouple economic growth from environmental pressure, so that living standards continue to increase while pressures on resources and environmental impacts can be substantially reduced. We modelled six main strategies to occur in the dematerialization scenario including: material and energy efficiency in construction and housing; a gradual transformation away from primary exports; a modal shift towards public transport; and lower food consumption rates. The environmental and other outcomes were compared with the modelling outcomes of a business-as usual scenario assuming current trends would remain unchanged.

In the dematerialization scenario, Australian material flows peak around 2030 at a rate of 65 tonnes per capita and then decrease to levels some 15% above current levels in 2050. Final energy consumption decreases marginally for about two decades before climbing slowly to be about 20% higher than contemporary levels. Even though $CO_2$ emissions from electricity generation drop substantially, the aggregate trend across the economy is similar to that of energy consumption. While the emissions are significantly less than for the business-as-usual economy, they do not approach aspired goals of 60% reductions or more. The increase in total water use is lower in the dematerialization scenario, by about a third of the increase without the policy actions we have tested.

Despite such reductions in resource use and emissions as compared with a business-as-usual scenario, the Australian economy would still grow in terms of GDP and employment, although not at a comparable pace. There are, however, limits to what can be achieved even by ambitious changes in the way Australia produces and consumes and the achievements outlined are still far above the targets set in the context of eg. greenhouse gas emissions. More fundamental changes in production systems, infrastructure, aspirations, and ways of living would be required to establish a low-carbon, environmentally sound society.

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*Figure 1. Direct material input in Australia in the dematerialization and business-as-usual scenario, 1950-2050, indexed*

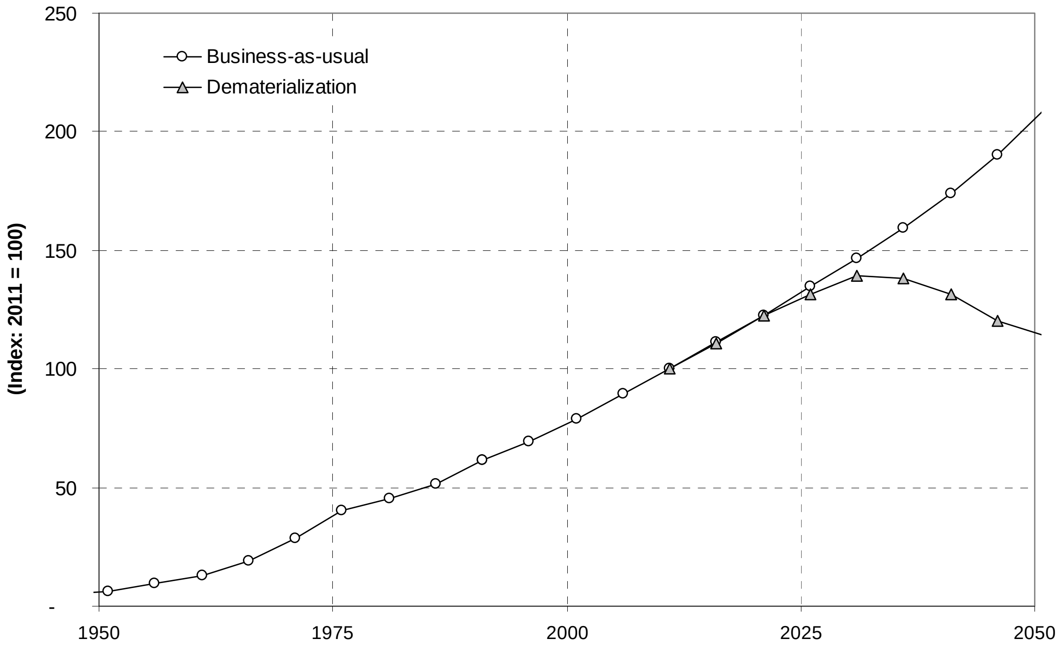



*Figure 2. Final energy consumption in Australia in the dematerialization and business-as-usual scenario, 1950-2050, indexed*

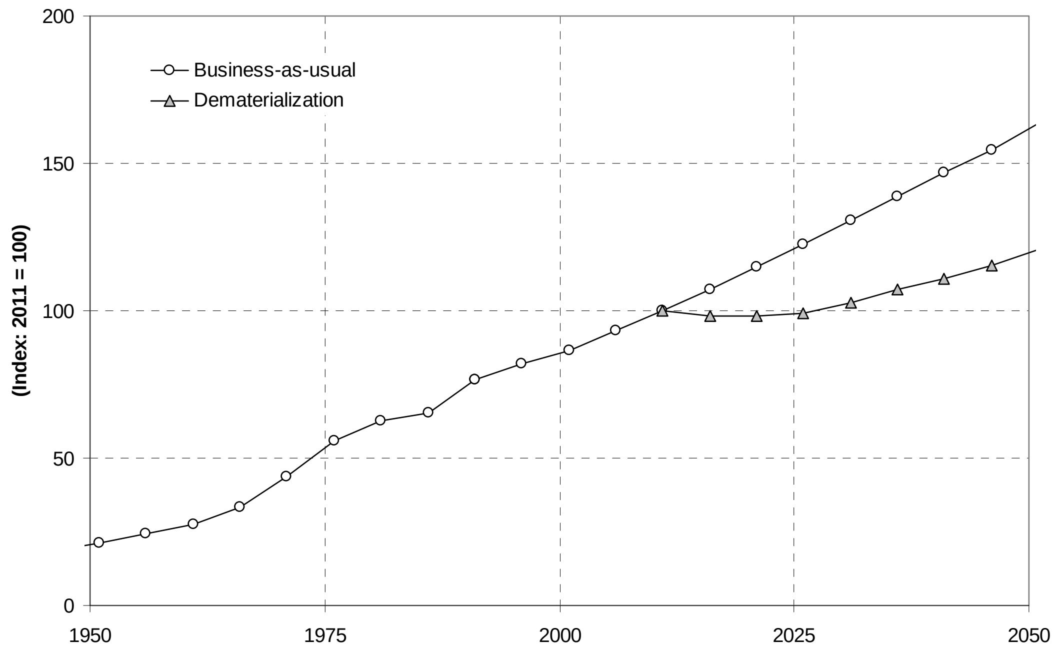


*Figure 3. $CO_2$ emissions from combustion in Australia in the dematerialization and business-as-usual scenario, 1950-2050, indexed*

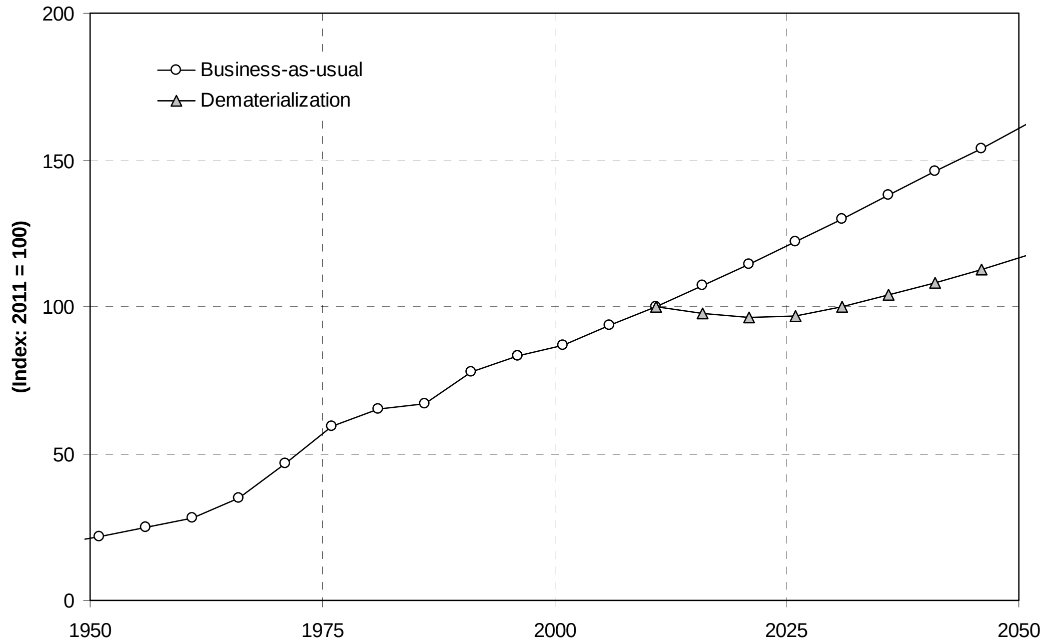
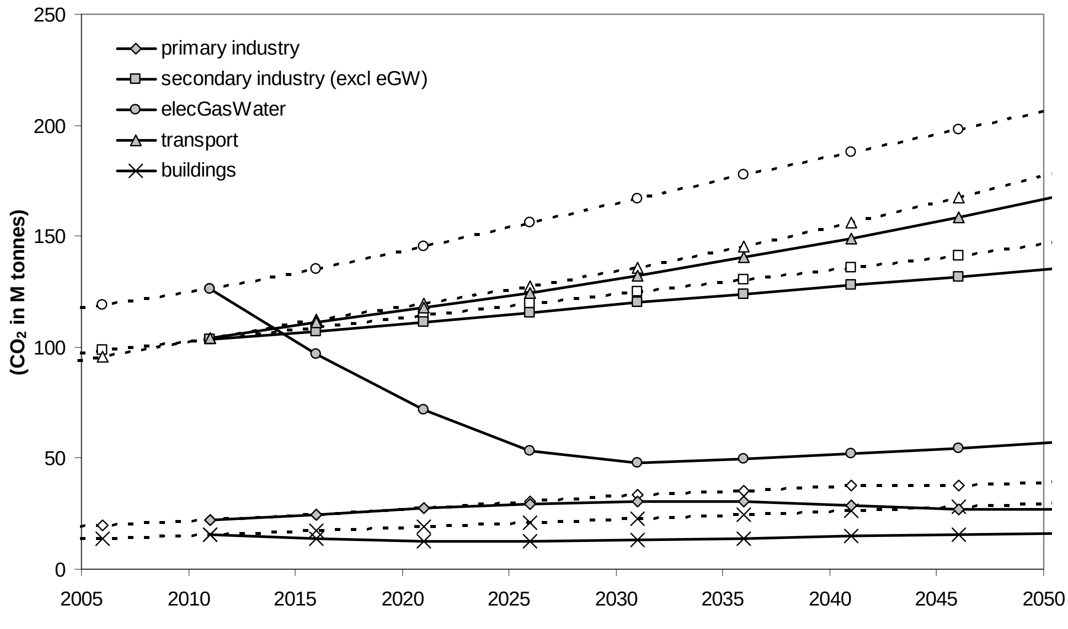



*Figure 4. $CO_2$ emissions by major sector, for the background (dashed lines) and dematerialization (solid lines) scenarios.*




Legend: dotted lines refer to the business-as-usual, full lines to the dematerialization scenario.

*Figure 5A. GDP estimate for Australia based on physical data in the dematerialization and business-as-usual scenario, 1950-2050, indexed*

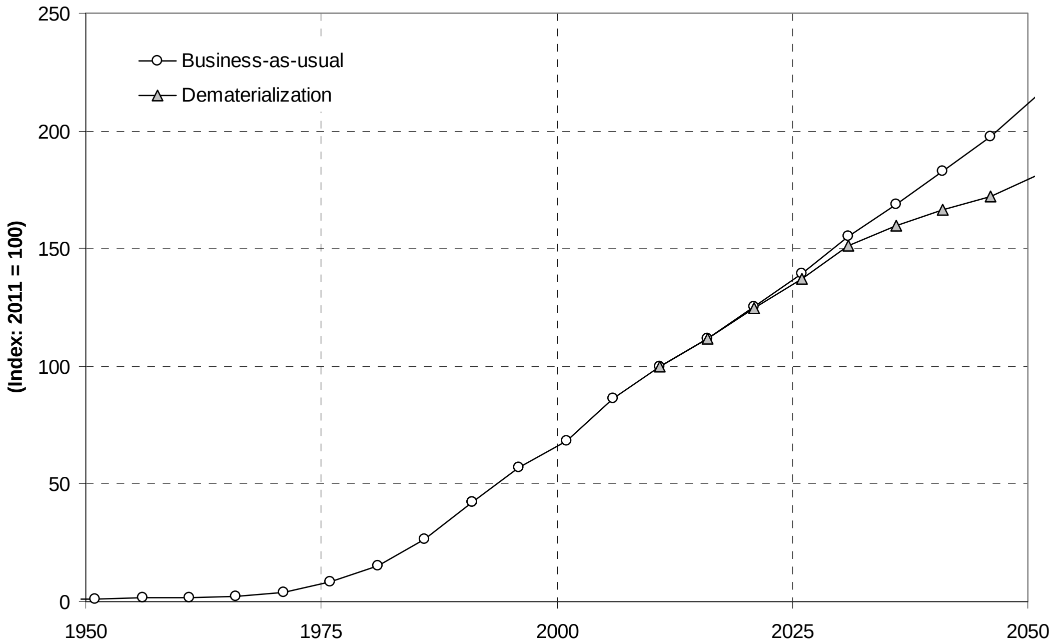



*Figure 5B. Per-capita GDP estimate for Australia based on physical data in the dematerialization and business-as-usual scenario, 1950-2050, indexed*

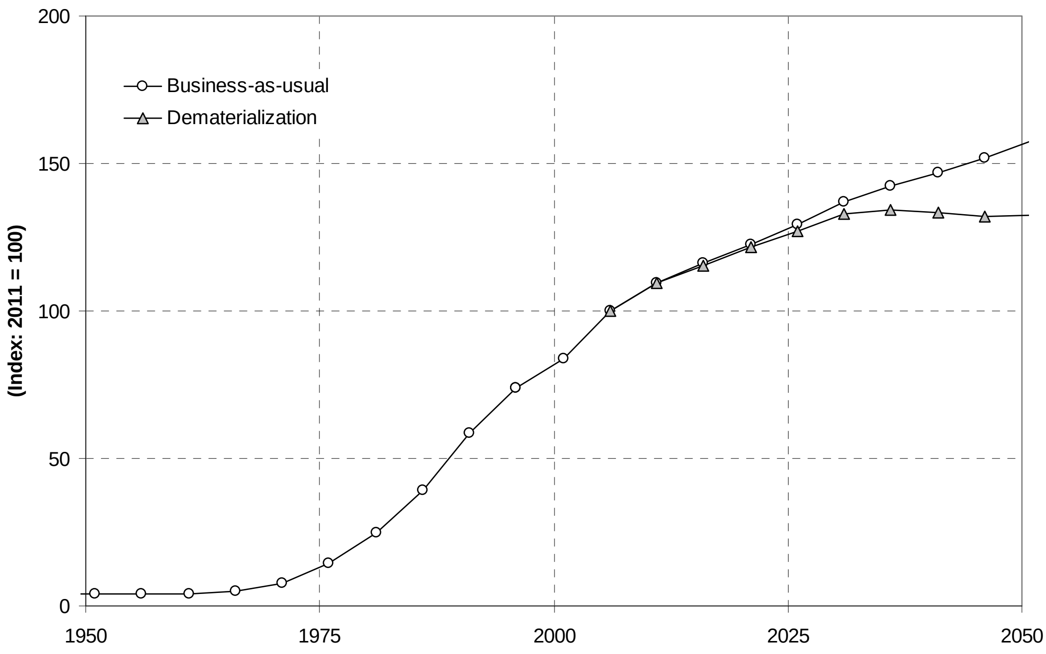


*Figure 6A Change in employment in high material flow sectors in Australia relative to 2006 levels, dematerialization scenario*

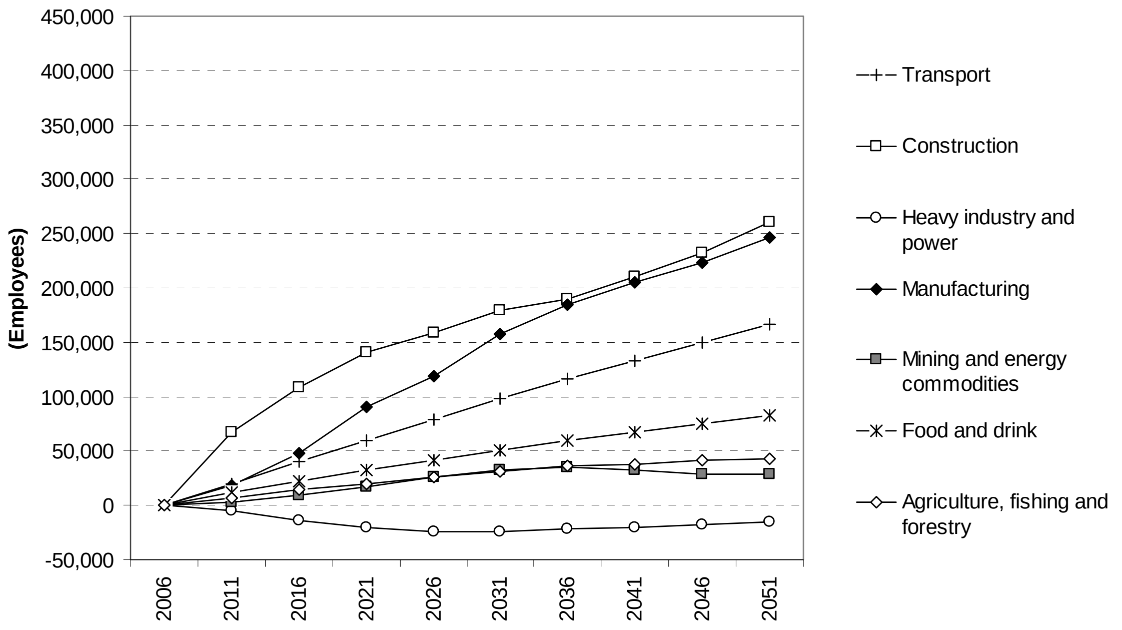



*Figure 6B. Change in employment in high material flow sectors in Australia relative to 2006 levels, business-as-usual scenario*

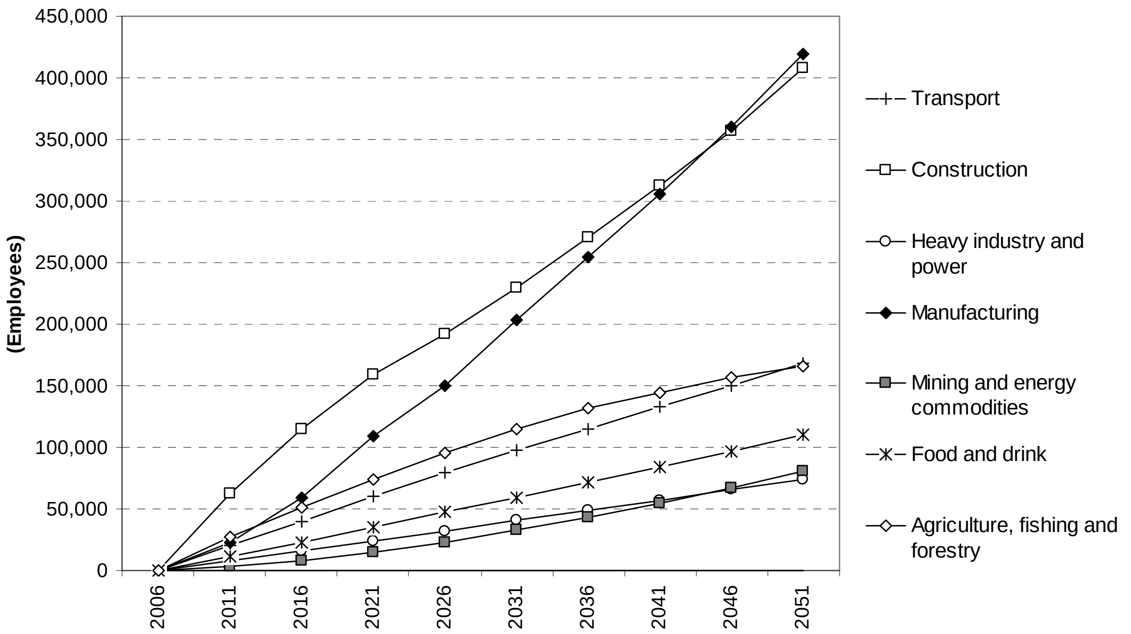


*Figure 7. Additional employment in Australia in the dematerialization and business-as-usual scenario, 1950-2050, million employees*