Raising Utility and Lowering Risk through Adaptive Sustainability: Society and Wealth Inequity in Western Australia

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Abstract

The Index of Sustainable Functionality makes it possible to analyse the sustainability of multiple systems within a domain from various perspectives. To illustrate how changes to wealth distribution since 1980 can impact sustainability of the economy, environment and society, the resource rich state of Western Australia's sustainable functionality was calculated from different wealth level perspectives. How wealth inequity may affect the stability of major systems including the social, terrestrial, water and mineral industry are discussed as are reasons behind changes in wealth and income distribution over the past 30 years. The ISF results show that from the perspective of society's richest 20%, poorest 20% and average wealth levels; and from the perspective of the environment, system decline can occur even when the economy reaches full functionality. Suggestions to improve functionality and long-term stability are made, with the major suggestion the introduction of a fund modelled on Norway's sovereign wealth fund.

Keywords: Index of sustainable functionality (ISF), Inequality, Sustainable development, Western Australia (WA), Norway, Wealth fund

1. Introduction

Wealth inequity has increased in the Australian state of Western Australia (along with the rest of the English speaking world) over the past 30 years, creating larger income differences between the rich, average wealth holders and the poor (Piketty & Saez, 2006). In this paper we aim to measure the sustainability of social, environmental and economic systems from the perspective of different wealth levels of society, the economy and the environment. The objective is to improve our understanding of how wealth inequity can impact the sustainability of social and environmental systems. Looking at sustainability from the view point of different wealth levels is important as wealth inequity is continuing to increase and has been shown to detrimentally influence the health of societies (Wilkinson & Pickett, 2009; Sapolsky, 2005), the economy, and the natural environment (Torras & Boyce, 1998). Wealth distribution thus has implications for the sustainable development of society.

Western Australia (WA) was chosen as the domain for this study as its population and environment are geographically isolated, and the economy is based predominantly on well defined mineral sales; Western Australia is one of the few remaining political entities where innovative change may still be possible.

Western Australia is one of the largest and wealthiest regions in the world with high natural resource wealth, a population of 2.2 million people and an average population density of only 1 person per square kilometre. WA covers a third of the Australian continent in area and has the highest Gross State Product (GSP) per capita of any state in Australia at US $53 178 compared with the state average of US $41 291 (Note 1). Western Australia's per capita production is therefore similar to Norway's ($53 451) that according to the World Bank is the top country world-wide (Note 2; Table 1). It is easy to see how this amount of production is achieved as according to the Department of Mines and Petroleum (2008), WA accounts for 19% of the world's iron ore production, 20% of alumina, 15% of nickel, 9% of (industrial) diamonds, 7% of liquefied natural gas (LNG), and 6% of gold with a total sales value of over $US 65 billion per annum in 2008 dollars.

WA was established as a British colony in 1826 with agricultural and livestock industries. The discovery of gold in the 1890s, nickel and iron ore in the 1960s, and major natural gas fields in the 1970s through to today has meant that, over time, large multinational mining and oil companies such as BHP Billiton, Rio Tinto, Barrick Gold, Exxon, Shell and Chevron (to name a few) have invested in the state and currently sell approximately 90% of the mineral resources sales (Note 3). Population increases have occurred rapidly through immigration and natural growth. The population has grown from 40 thousand in 1890 to 2.2 million today, representing a 3.4% annual growth over last 120 years.

Environmentally, Western Australia is one of the world's international biodiversity hotspots (Conservation International, 2009), renowned for both the diverse terrestrial biodiversity and the low nutrient endemic biodiversity of the coastal waters; the Southwest region of WA alone, with less than 20% of the total area, maintains 5710 known native species of flora and fauna, with a high rate of endemism (79%). (Beard, 2000). This change has occurred since colonisation due to clearing for agriculture and development to cater to the increasing population, clearing land for the continued expansion of the wheat and forestry products industries and the increasing over fishing of the Western Australian coastal waters. This growth has led to significant reductions in habitat for much of the endemic terrestrial and marine flora and fauna. To protect the environment, social fabric and economy of Western Australia, the State Sustainability Strategy (2003) was developed. The report defined sustainability as follows:

"Sustainability is meeting the needs of current and future generations through the integration of environmental protection, social advancement and economic prosperity".

This definition is essentially an adaptation of the Bruntdland report that uses the triple bottom line (see definition of terms Appendix A), now regularly used in industry that segments sustainability according to the economy, society and environment. The weakness of this definition is that it is impossible to forecast what future generation's needs may be; and what is one person's need may be another person's greed.

Many indices have been advanced to measure sustainability (Singh et al., 2008), for example the composite sustainable development index (Krajnc and Glavic, 2005), but there is still no standardized methodology to enable consistent measurement and identification of sustainable options (Azapagic and Perdan, 2000) and only recently (Imberger et al 2009) has a well defined definition of sustainability been defined:

"An action on a system in a domain is sustainable, from a particular perspective, if that system does not lose its functionality as defined from that perspective"

This definition is robust once a system in the domain and the various associated perspectives are defined, the functionality of the system is defined in an unambiguous way, and this functionality is measurable with normalized indicators; a value of one implying fully functional and a value of zero meaning no remaining functionality. (Kristiana et al., 2010). The technicalities of this definition of sustainability may be illustrated with a simple example. Suppose we define a rural precinct as the domain, such as the wheat belt of the South West of Western Australia. One system could be the wheat industry from the farmer to the exporter. Two perspectives could be the local wheat industry and that section of the local community that has traditionally lived there for the biodiversity. The function of the wheat industry from that industry's perspective is to make a profit; sales could be an indicator and if profits exceed costs this activity would be fully sustainable. The difficulty here is already clear, do we include all externalities in the measure of cost. Nevertheless, once agreed upon, sales minus costs become a quantitative measure of sustainability from the wheat industry's perspective. From the "green" community the function of the wheat industry could be to provide wheat for domestic consumption in the precinct and the indicator then becomes production minus local consumptive need. This group of people would further, most likely, add an indicator such as the number of species that inhabit the precinct. Fully functional would mean a number equal to or great than that present before the wheat industry and anything less, would in the eyes of the green constituents, mean less than fully functional.

Imberger et al (2008) and Kristiana et al (2010) showed that this methodology allowed for a more rational debate between conservationists and developers as a weighting was attached to each indicator, reflecting the importance the community as a whole attaches to a particular functionality. We are thus left with a consensus functionality and a functionality as viewed by vested interests; hence the methodology clearly declares people's priority and also allows for community change of priorities (change in weightings) without corrupting the absolute changes as these are reflected in the values of the indicators.

The importance of defining functionality from different perspectives is perhaps best illustrated by the use of the Gross Domestic Product or GDP. Originally it was defined simply as a measure of the flux of money. It is used, almost universally, as a measure of economic progress or well being. Nevertheless, if one takes the flux of money as a result of lawyer's fees in a murder case, then these contribute to the GDP and from the layer's perspective this a good thing, but from society's perspective not having a murder take place in the first instance would be better, but this would contribute negatively to the GDP. (see also Willard, 2002; Costanza and Patten 1995; Nourry, 2007; Fricker 1998)).

Numerous publications exist that examine systems and domains using the triple bottom line (Willard, 2002;

Krajnc & Glavic, 2005); this is an implicit recognition for a need to define perspectives. However, so far society's perspective has always been lumped into an average perspective. With the growth of wealth inequity (ABS 2009), it is intuitively obvious that the world looks different whether a person in the bottom or top income or wealth bracket. In Australia, over the 3 year period from 2003 to 2006 the number of households who had negative wealth nearly doubled as did the number of households that had a wealth of greater than AUD $10 million (ABS 2009; Headey et al. (2004)). Further, not only does the world look different from different perspectives, but also, as shown by Torras and Boyce (1998), income equality, education and power variables are highly correlated to pollution levels and that the "results provide fairly robust support for the hypothesis that greater inequality in the distribution of power, and or wealth, leads to more pollution"; the environment is impacted by wealth inequity. (See also Wilkinson and Pickett, 2009).

Wealth and income distribution are commonly measured using ratios such as P90/P10 and P80/P20. The former ratio, for example, directly measures the wealth or income of the 90th percentile individual or household relative the wealth or income of the 10th percentile household or individual. Household wealth distribution (P80/P20) (Note 4) by Australian states in 2004 is shown in Table 1 where it is seen that Western Australia had the lowest wealth inequity (highest equality) among the Australian states. The highest to lowest wealth quintile ratio (P90/P10) also puts WA among the lowest inequality states. These figures may, however, be skewed, if it is remembered that in Western Australia, by the nature of being dominated by multinationals, the very wealthy live mostly out of the State. Figure 1 shows relative child poverty rates correlating in Australia with inequality, and that both of these measures of social cohesiveness have become worse since 1980. There is a sharp drop in inequality in 2003, possibly a result of the dot-com crash reducing *relative* poverty rates, although the overall trend upward over decades is strong. While we must consider that this correlation may not be causal, recent studies by Sapolsky (2006) have shown that social inequality causes stress that leads to, among other social problems, immune related health and mental deficiencies among populations of primates, including humans.

In a previous sustainability analysis of Western Australia, using the Index of Sustainable Functionality (ISF), described in more detail in Section 2, Imberger et al. (2007) showed that for the 20 years to 2003, the functionality of the West Australian economic system improved, while the individual and social systems did not. This result resembles other reports that show continued expansion of the Australian economy (since 1973-74) may be making the *average* Australian poorer, not richer (Lawn and Sanders, 1999) and introducing a greater element of "relative poverty". Financial assets, especially equity investments and superannuation, are heavily concentrated in the hands of high-income earners (Creedy and Tan, 2007), and this may be causing social and environmental outcomes that are not intended but are a consequence of increasing wealth inequity and the so called "relative poverty" factor described by Patel and Kleinman (2003) and Murali and Oyebode (2004).

The connection between strong wealth inequity and social malaise provides the impetus for investigating sustainability from the perspective of wealth levels to determine whether:

(1) Wealth inequity can lead to instability in social, environmental, or economic systems; and

(2) The ISF can be used to analyse changes in wealth inequity over time and suggest improvements based on measured results.

Therefore in this paper we look at Western Australia's sustainability from the perspective of the wealthiest 20%, poorest 20% and mid-wealth level of households, as well from the economic and environmental perspectives. We do this using the Index of Sustainable Functionality (ISF) developed by Imberger (2007) that takes a quantitative approach to measuring sustainability.

2. The Index of Sustainable Functionality

To summarise, the Index of Sustainable Functionality (ISF) measures the sustainability of a geographical region (domain), in this case WA, taking both systems *and* perspectives into account. The steps for calculating the ISF are described in Figure 2 and a number of terms used are in the definition of terms. Table 2 shows the Systems/Perspectives matrix that is used to assess the ISF. The ISF was chosen for this paper because, as well as being multi-dimensional, it also allows indicators to be chosen that are directly calculated for the state (Note 5). To date the ISF has been successfully used to assess the impact of a major development (Marina Bay) in Singapore (Kristiana et al., 2009), the sustainability of the Gold Coast in Australia (Cirella et al., 2006), and of Western Australia from 1970 through to 2003 (Imberger et al., 2007).

To summarise the ISF, for the domain (D) of Western Australia, there are a number of systems (K^i) (such as the social and mineral); and (J^i) perspectives in which to look at such systems (for example from the perspective of the wealthy or poor). Functions (F^i_{jkl}) are the outcomes that each system provides, where L^{jk} are the number of functions in the matrix element (j, k), as measured by their respective indicators I^i_{jklm}. For example, a function of the terrestrial system from a social perspective might be to produce food for consumption; with indicators developed to analyse the performance of the system (e.g. how much food is produced). The set of objective indicators are then normalised (M^i_{jkl}) to values between zero and one. Following on from this example, if not enough food is produced for society to grow and prosper; the normalised outcome would clearly be less than one.

Weightings (W_{jkl}^{i}) represent the importance allocated to each system (for example whether water is more important than mining to the community, and if so by how much). In this way, the ISF methodology also introduces a clear demarcation between the objective indicators that reflect the functionality of systems and the relative importance of these functions as determined by community consensus. This is calculated by and reflected in the weightings further described in Section 2.3.

As data capturing improves and new perspectives or indicators emerge, improvements to systems can be made by implementing the ISF methodology and measuring indicators in real-time. When the ISF uses community evaluated weightings reflecting current value systems, the ISF becomes an objective measure and can contribute to Adaptive Sustainability, where feedback from previous results can be used to improve long-term functionality. Thus the ISF offers a quantitative measure of sustainability and provides the opportunity to dissect and identify areas of unsustainable practices that might require further investigation or can be improved upon.

2.1 Domain, systems and perspectives

The Domain chosen was Western Australia and includes offshore areas totalling 2.5 million square kilometres (one third of Australia). These areas are included in Western Australia's GSP and export income accounts.

The systems and perspectives used in the ISF calculations are provided in the Systems/Perspectives matrix (Table 2). Each system (social, terrestrial, water and mineral industry) has its own perspectives and both systems and perspectives should not be viewed in isolation.

Perspectives were chosen to provide results that could assess whether wealth inequity leads to instability in any systems or in WA overall. As such the perspectives of the wealthy, poor, mid-wealth, environment and economy were included in the ISF analysis. The wealthiest of the population are defined as having a mean annual income (P90), as provided by the Australian Bureau of Statistics, in the top 20% of society that reside in WA. Similarly the poorest 20% of the population has a lowest quintile mean income (P10). For the average wealth household, the mean income of the median wealth holder was used (P50). Western Australia is a useful example for this analysis as it is growing rapidly, and over the past 30 years there has been a significant change in wealth distribution.

2.2 Functions and indicators

Functions and indicators that feed into the Systems / Perspectives matrix (Table 2) are described in Appendix B. The ISF requires careful selection of data such that it is both available over time and can be used as an indicator of system functionality. The choice of functions and indicators were made by reading research reports and published papers on sustainability, financial markets, government policy, health trends, environmental functionality and social responsibility. Data that reflected the systems functionality was tested for suitability, availability and as having lower and upper bounds defining non-functioning and fully functioning respectively (for normalisation). For example, infant mortality ($F_{4,}I_6$) was used as a measure of the progress of society as it was described as important measure of progress by Freemantle et al. (2006). Therefore as infant mortality data exists from a reputable source (Australian Bureau of Statistics), and has been measured over time through surveys in 1980, 1990, 2000 and 2006, it was included as one indicator of functionality for the social system. The same methodology was applied to the economic perspective where growth (change in GSP) ($F_{10,}I_{14}$) and employment ($F_{11,}I_{15}$) are indicators that represent economic system functionality and are available over time.

Judgement regarding what is, for example, "significant" environmental damage or "fully functional" employment is open for argument and therefore the choice of indices, data and normalisation functions (also described in Appendix B) must be checked for sensitivity. It is important that upper and lower bounds, including the reasons for choosing them, be transparent so that results can be reproduced and accurately identify changes over time. Bounds that are absolute should be chosen wherever possible, but this is not critical. By way of example, the ISF report on Western Australia (Imberger et al., 2007) used a 2% renewable energy upper bound as fully functional as this was the State's target at the time. In 2009 the use of renewable energy was over 3% of production, so the targets are moving, but the indicator (F_7,I_9) still represents a fully functional situation. When the ISF is recalculated using higher targets, the improvement over time will be captured in this change. Cleary, absolute bounds are preferable when data is available. In this example the fully functional bound would be that which makes Western Australia carbon and water neutral, bringing into focus the fact that bounds and indicators are sometimes conditional on other indicators.

The Centre for Water Research Real Time Management System (Note 6) previously used to evaluate functionality in surface water systems was used to calculate the ISF using encapsulated fixed data and variable bounds for indicator normalisation. Using this program it was possible to calculate the ISF from each perspective for each system as well as test the robustness and sensitivity of results by changing indicator bounds and weightings.

2.3 Weightings and aggregation

System weightings for ISF aggregation were based on results from Google Trends (Ginsberg et al., 2009) and are provided in Table 3. Google Trends provides the ability to measure the amount of traffic over the internet on a particular topic in a geographical area. While difficult to know if this matches society's values exactly, it is most likely a reasonable measure of importance and as such was used for system weightings by using the search terms "people", "mining", "water" and "land" for Western Australia. The robustness of this method was tested by using the same terms in other Australian states with results that matched expectations. As an example, the term "financial services" was more important in New South Wales (NSW) than in Western Australia, which is understandable given that the financial services industry is a larger factor in the economy and daily lives of people in NSW compared with those in WA.

Equation 1 describes the ISF aggregation of indicators:

$$ISF = \sum_{j=1}^{J^i} \sum_{k=1}^{K^i} \left[\frac{W_{jk}^i}{L_{jk}^i} \left\{ \sum_{l=1}^{L_{jk}^i} \frac{1}{M_{jkl}^i} \sum_{m=1}^{M_{jkl}^i} \left(I_{jklm}^i \right) \right\} \right] \tag{1}$$

where weightings for perspectives, functions and indicators were considered equal and Equation 2 is required.

$$\sum_{j=1}^{J^i} \sum_{k=1}^{K^i} W_{jk}^i = 1 \tag{2}$$

For further information on the ISF that includes a full introduction and other examples of its application, the reader is referred to Imberger et al. (2007).

3. Results

After normalising and aggregating the indicators used in Equation 1 and plotting using a 3-year moving average, the ISF results are shown in figures 3 through 6. A 3-year moving average was used for all figures as it provides the best results in terms minimising sensitivity and volatility over years where annual data might be unavailable, while still capturing short-term changes in functionality. Data was checked for sensitivity and data aggregated only where at least three indicators were available.

Reviewing the aggregate ISF result plotted against real gross state product per capita (GSP) (Figure 3) shows that the rate of increase of real GSP is higher than the ISF over the period 1990 to 2009. Removing the mineral system from the ISF (ISF without Mineral System) shows a greater disparity between the increase in GSP and the ISF aggregate for Western Australia. While the real GSP per capita has increased, in this period, by 60% to \$64 000, the ISF has improved overall by less than 10%. Without the mineral system the ISF has decreased by 16% from 0.58 to 0.49. This shows that:

(1) The increase in gross state product is not leading to any significant improvement in sustainability; and

(2) The mineral system is becoming increasingly important to the state, especially in 2007 and 2008, with the assumed weightings.

The second point deserves comment. The overall ISF shown in Fig 3 includes the weight for each system, as determined from the frequency of searches on Google. It is thus a true measure of people's interest, but will be strongly biased towards people's interest and aspirations "what are my shares doing" rather than the importance to people's life. Clearly, it also is biased towards the wealthy that use the internet as a source of information; a poor person, with no shares or wealth to think about would not show up in a Google statistic.

Figure 4 (all systems) shows a terrestrial system maintaining its functional level from 1990 to 2004 but displayed a sharp decline from 2005 onwards; this was caused, in part by a decline in the value of agriculture, forestry and fishing (I_{20}). The water system was close to semi-functionality (ISF 0.55 to 0.60) and showed little change from 1995 to 2007. The striking result is the improvement in the minerals system from 1993 until 2008 that occurred during constant or slightly declining functionality for all other systems.

Aggregating the perspectives across all systems (Figure 5) shows a steady improvement from the perspective of the average wealth holder from 1993 to 2008; and similarly for the poor to 2006, but then a decline to 2008. The notable results here include:

(1) The overall dysfunction from the two lower wealth level perspectives, but especially from that of the poor, while the ISF from the wealthy perspective pretty much tracks that of the economy, to about 2000, after which time the economy is showing a decreasing benefit to even the wealthy; money is increasingly moving offshore.

(2) From an environment perspective these results confirm the low functionality already alluded to by Imberger et al. (2007), but also show that the rally between 2004 and 2007 was short lived.

(3) The average wealth holders show steady overall progress regardless of environmental or economic changes.

(4) The wealthy are fine no matter what the economy is doing; although the functionality of the wealthy (and average wealth households) is significantly lower in the social system than for all systems (Figure 5 vs. Figure 6).

In Figure 6 we show in more detail, how the social system (unweighted and separated from the aggregate of all systems) appears from the different wealth perspectives. The data show an improving social system (K_1) from the perspective of the economy (J_5) from 1993 to 2008. Other noticeable trends include the volatility of the economic perspective, the long-term decline from the environmental perspective, and the large drop from the perspectives of the wealthy (J_1), mid-wealth (J_3) and especially the poor (J_2) from 2005 to 2008, after a slight overall gain for all from 2001 to 2005. The initial improvement of the social perspectives in the growing economy of 2003 to 2005 appears to have been reversed during the very strong growth period 2006 to 2008. The precipitous drop in functionality coincided with very high housing costs and strong population growth. From the perspective of the poor, a steady improvement between 1982 and 1994 was wiped out by 1998 (coinciding with Asian Financial Crisis) and dropped further through to 2009. During the 27 years to 2009, functionality from the economic perspective was significantly greater than from the other perspectives, with close to full functionality occurring in 2007/08. Overall there was a decline in the social system from all perspectives except the economic (marginal increase) over the three decades to 2009. From the perspectives of both the wealthy and mid-wealth, there was a significant departure coinciding with the 1992 recession, leading to an increase from 1994 from both perspectives until 2005 when housing costs grew substantially faster than wages (I_5) and crime increased (I_2). The overall reduction in ISF values from 2007 is a result of high living costs relative to wages that do not increase proportionately.

In summary, the above results show that the functionality of all systems from all perspectives (except the economic) has not improved, despite the very high economic growth and full employment conditions in the period from 2004 to 2008. We can also see the importance of the mineral system to the state, but, as pointed out above, this is more an illusionary importance as it is based on a weighting of "the gold at the end of the rainbow". From the poor perspective the social system showed a one-third decline in functionality from 1980 to 2008 while real GSP per capita increased substantially. Spending on social and environmental improvements has therefore not kept pace with the rise in gross state product; items such as water, electricity, health care etc are all rising at a rate commensurate with the increase in income of the wealthy sector. Land use change and pollution accounts for much of the impact on the environment.

4. Discussion

The likely explanation of the above described trends is first, that the resource wealth is mostly benefiting the upper 20% wealthy and overseas shareholders; the resource industry seems to be almost irrelevant to the average and below average wealth sector of the Western Australian community. Second, the resources industry in Western Australia dominates the economy and is an industry that benefits by maximizing the extraction rate. This means that labour is always in demand, skewing the salary scales in the state, making it difficult for the maintenance of other economic activities.

4.1 Destination of resource wealth

Western Australia accounts for one third of Australia's total export income, mostly in the form of commodity sales that were AUD $71.8 billion ($US 65 billion) in 2008. Although WA produces 6% of sea-borne liquefied natural gas (LNG) 65% of Australia's gold (24 t / annum) and holds 6% of the world's total gold deposits (Geoscience Australia, 2008), the largest component of exports is the 19% of the world's iron ore that is produced in the state, making it the third largest producer in the world with export income over US $25 billion per year (DMP, 2008). The iron ore is primarily used in steel manufacturing in Japan, China and South Korea.

During 2008 revenue of one dollar of minerals sold from Western Australia was estimated to be distributed according to the numbers shown in Figure 7. The largest component of the revenue (BHP, 2008) goes to the company as profits for shareholders. The shareholders of these companies (primarily Rio Tinto, BHP Billiton, Shell & Chevron) are based world-wide, and we have estimated that less than 3% of shareholders (by value) reside in Western Australia. The capital inflow for project development is considered as part of the local spending.

The majority of iron ore employees, contractors and suppliers are based in Western Australia. According to the Department of Mines and Petroleum (2008) it is estimated that 23,000 people are employed as a result of the iron ore sales, which is 2.6% of the 1.3 million people employed in the state (ABS 6202.0, 2008). For the mineral industry in total, including contractors and payments to oil and gas workers, 66,000 employees (5% of workforce; 3% of population) received, on average, $120,000 each ($7,900 million in total). Local and international suppliers share the operations expenditure and thus, it is estimated that between 21 cents and 30 cents of each dollar of mineral sales (including royalties and federal government payments) remains in Western Australia.

In 2008 royalty payments (including oil and gas grants) were $3,667 million (DTF, 2009), the general public received 4.8 cents in the dollar in the form of taxes and royalties, which was $1,665 each. BHP (2007) states that its economic contribution "comprised $1,108 million to the Federal Government, $344 million to State Government, $6 million to Local Government and $12.5 million in direct community contributions." Revenue was over $6,500 million and earnings over $3,400 million. Thus in this case 5% of sales went directly to the state, even when including the amount returned from the federal portion (distributed almost proportionately to state population).

The above estimates are consistent with research by Ye (2008) who showed that $20.4 billion (NPV) would be returned to the West Australian population over 20 years to 2025 when assuming high growth ("Scenario 1") iron ore exports. This equated to $510 per person in 2003 Australian dollars.

When taking into account research by Layman (2006) and Ye (2008) that included "the effect of an inflow of labour and capital into a home state from other states or regions" and "deviations in per capita consumption aggregated over the population that would have been there without the project", the result was a net benefit of $11.8 billion over 20 years in 2003 dollars. With a population of 1.9 million people in 2003 this equated to $6,200 per person in 2003 dollars. The value is likely to be higher in the future however as iron ore prices continued to increase from 2006 onwards.

Oil and gas is Western Australia's second largest export, but as the majority of reserves are found in federal waters, the royalties to the state (including Commonwealth grants) are even smaller than for iron ore (DTF, 2009). This is the case even though the sales are included in WA's GSP.

Thus, in summary:

(1) Approximately $200 billion of iron ore sales over 20 years (asset depletion of $105 000 per capita) was expected to return, on average, $6,200 to each West Australian (non resource industry employees) in total over 20 years from 2005 in 2003 dollars ($310 per person per year).

(2) Between 20 and 40 cents of every dollar of mineral sales (including oil & gas) contributes to the West Australian economy in terms of spending; or 60 to 80 cents of each dollar in Gross State Product does not reach the state (Note 7).

Western Australia's high mineral wealth and low population means the state maintains low unemployment rates and a strong balance of trade during periods of high commodity prices (Note 8). Low state government surpluses ($647m in 2008-09) (DTF, 2009) can be explained by low royalty rates (as little as 2.5% for BHP and Rio Tinto iron ore production to 7.5 % for coal) and a federal taxation structure that returns less to the state than is removed ($8 billion net outflow in 2008), as the goods and services tax (GST), company tax and personal income tax are collected at a national level and distributed with reduced flow-back to wealthier states under the principal of "horizontal fiscal equalisation" (DTF, 2009).

4.2 Income distribution patterns

Piketty and Saez (2006) showed that since 1980, among English speaking countries including Australia, wealth has been increasingly generated from high end salaries, rather than earnings from capital or business income. Over the same period the share of total income of the top 1% income earners in Australia went from under 5% in 1980 to over 9% by 2000 (Atkinson and Leigh, 2006).

In the United States between 1972 and 2001, income (in inflation adjusted dollar terms) at the 99th percentile rose 87%; at the 99.9th percentile rose 181%; and at the 99.99th percentile rose 497% (Krugman, 2006). At the same time the average hourly wage, since 1970, for non-supervisory workers actually decreased during this period. Krugman (2006) suggested that "the growth of inequality may have as much to do with power relations as it does with market forces". Recent studies point to a similar trend in Australia (Atkinson and Leigh, 2006); and paradoxically disclosure of executive pay is often cited as one of the causes of this escalation which has continued to climb in the face of attempts to curb its growth (Kovacevic, 2009).

In Australia, CEO pay has increased among the top 50 publicly listed firms from 18 times the average worker salary in 1980, to 27 times in 1992 to 98 times in 2002 (Atkinson and Leigh, 2006). This has resulted in the increasingly disproportionate allocation of income to the top 1% of income earners. According to Mandelbrot and Taleb (2005) "we live in a world of winner-take-all extreme concentration" where "one percent of the U.S. population earns 90 times what the bottom 20% does, and half the capitalization of the stock market (close to 10,000 companies) is in fewer than 100 corporations." The situation is similar in Australia where 50% of company profits are generated by just 10 corporations (BRW, 2008) (Note 9).

Although WA accounts for a third of Australia's export income, few executives of Australia's largest corporations live in WA (Note 10), and even fewer executives of multi-national corporations reside in the state (Note 11). As a result Western Australia does not display the extreme income peak and appears slightly more equitable than the rest of Australia (Table 1). As the power centres are outside WA, this may be contributing to decisions that do not improve the environment or the social systems, hence the declining environmental and social systems, especially for the poorest 20% as observed in the results.

4.3 Comparison with natural systems

In natural systems it has long been recognised that diversification leads to stability (Patten and Jorgensen, 1995) and that ecosystems that rely on one source of nutrients are more susceptible to instability (Gunderson and Holling, 2001; Gotts, 2007). Thus reliance on one source for nutrients is more likely to lead to instability and large dramatic changes including declines. After reviewing the ISF results, we propose that an analogy may be drawn to a state that is increasingly reliant on a single economic activity, non-renewable resource sales; this will, most likley reduce the its resilience to external shocks such as price fluctuations or withdrawal of a large market sector, such as China. Declining agriculture and manufacturing sectors, as a proportion of total economic activity, have meant an increase in the power of the mineral industry in relation to other sectors of the economy as the State relies more heavily on only mineral activity for revenue and employment.

This decline is represented in Table 4 that shows the changes in select industries as a percentage of total production in Western Australia from 1990 to 2008. Noticeable in this table is the dramatic drop in agriculture, education and finance as a proportion of activity. This shows that industrial diversification has decreased over time. The number of patents filed by residents of the state on a per capita basis has also reduced (by 16% from 1995 to 2007) (IP Australia, 2007), indicating reduced diversity of intellectual activity over this period that will lead to instability in the long term.

Thus the increasing reliance on mineral exports may be leaving WA open to greater instability and declines in system functionality on two fronts (during periods of rapidly increasing or decreasing prices). Given the results of the study, that indicate an improving economic system, but a decline of overall sustainability or stability, it is worth investigating alternatives to the English speaking country model that has recently trended toward increased wealth inequity.

4.4 Comparison with Norway

Norway is similarly endowed with natural resources (mostly oil & gas), with a similar GDP and population to Western Australia, but maintains much greater equity in wealth and income distribution among its population (LIS, 2009). While there are significant differences, such as Norway being a small country and Western Australia being a very large state of Australia, there are many similarities, including the fact that WA maintains full ownership of its land based resources. As such WA maintains the ability to implement royalty structures as well as control when and how these resources are developed. By way of international comparison, Norway has similarly high mineral (oil and gas) wealth and export values to WA's total mineral production (Note 12).

Contrary to the current West Australian scenario, where mining laws are structured such "that no person should hold any mineral rights without being required to develop them" (Hunt, 2001), are the models offered by Saudi Arabia and Norway. King Abdullah of Saudi Arabia, for example, said regarding new oil finds, "leave it in the ground, with grace from God, our children need it." (FT, 2008) Norway by comparison (noted for best resource wealth management practices world-wide) is not keeping its wealth in the ground, but is similarly keeping it for future generations (and diversifying its assets at the same time) through the use of a sovereign wealth fund (NMF, 2008). As mentioned in the introduction, it was Norway's Prime Minister Brundtland that introduced the current definition of sustainability during the 1980s.

Norway is one of the most equitable countries in the world with a P90/P10 income ratio of 2.8 (Western Australia's is 4.1). According to UNICEF (2007) Norway has one of the lowest child poverty rates (one third of WA's). Figure 8 shows a comparison of income inequality (P90/P10) ratios and child poverty rates across the United States, Norway, Australia and WA in 2004 using data from the Luxembourg Income Study (LIS, 2009). This shows a trend of lower social dysfunctions among more equal societies. Norway has therefore been able to retain the benefits while side-stepping the pitfalls of high natural resource wealth by creating a sovereign wealth fund (NMF, 2008) that channels export earnings from its resource wealth into other investments while at the same time maintaining one of the world's most equitable societies (LIS, 2009). Some of the best performing indicators of social progress (such as low child poverty and infant mortality rates) are found in Norway, and according to the Norwegian ministry of finance the fund (established in 1990) is the largest in the world and has a value of $400 billion (NMF, 2008) (Note 13).

Other positive effects of saving and diversifying include lower exchange rates (helping other exporters) and stability during periods of high volatility in international markets. This was seen in the 2008 financial crisis where the Australian dollar fell 35% against the USD in a matter of months while the Norwegian Kronar was considered safe by comparison (appreciated against the USD). Furthermore the number of patents per capita filed for Norway increased by 100% from 1995 to 2007 (US PTO, 2009). This represents a dramatic departure from the 16% decline in per capita patents in WA over the same period (IP Australia, 2007).

Thus for long-term sustainability of all systems, from each wealth level perspective and overall, rather than just for economic progress for the economy's sake (economic perspective), Western Australia should follow the Norwegian model of non-renewable resource management. Figure 9 shows the approximate affect on the destination of export revenue with a 5% contribution from mineral exports to a WA Wealth Fund. It should be recognised that this includes a critical assumption that the investment decisions and size of projects are the same even with this effective reduction in the project revenue and profits.

4.5 ISF with Introduction of a Wealth Fund

Figure 10 shows the effect on wealth inequity in WA if a 5% contribution ($3.5B in 2008) was directly allocated toward the poorest 20% of the population. Although a fund modelled on Norway's is advocated rather than this direct allocation, under this scenario disposable household income for the poor would rise 50% (from $308 per week to $461 per week) reducing income inequality among the population (P90/P10) by approximately 20%. As WA's major mineral commodity prices fluctuate more than 5% (Note 14) each year without disruption to long term projects, the introduction of a wealth fund during periods of high commodity prices would not significantly impact exports or employment. Projects that would be compromised by a 5% revenue change during high commodity price periods are not sustainable in the long-term regardless and if commodity prices were to fall below a certain level then percentage contributions could change in line with a commodity prices, as per the

Norwegian fund model. Obviously there is also a need to recognise the capital contribution of each project and the specific nature of certain industries (such as long term LNG contracts).

The introduction of this fund has been introduced to the ISF calculations using controllable drivers. Drivers of the ISF are those indicators or bounds that affect the ISF results and can be manipulated. We define controllable drivers as those drivers located inside the domain that are changeable through policies, tools or systems using current technology. Uncontrollable drivers are affected by changes outside the state or are a direct result of controllable drivers. Appendix C lists the controllable drivers that were adapted to produce the ISF results that included the introduction of a sustainability fund (Figure 11).

In Norway fund assets are invested internationally in order to avoid overheating the local economy and to reduce the likelihood of corruption (NMF, 2008); with earnings spent on programs that improve societal outcomes. Similarly Figure 11 shows the effect on functionality in WA of a fund that has collected an average of 5% of exports (on top of current royalties) for non-renewable exports when commodity prices reached certain levels (Note 15).

The result of the introduction of a sustainability fund is a dramatic 18-25% improvement in overall functionality compared with the current ISF between 1990 and 2008. Under this scenario fund interest and dividends are invested in long-term projects to protect the natural environment and improve social functions of society through spending on infrastructure assets such as public transport and education.

5. Conclusion

The Index of Sustainable Functionality showed that, for the resource rich state of Western Australia, the economic functionality has improved over the past three decades, while from all wealth-level perspectives, and especially for the poorest 20% of society, there has been a reduction in social functionality and the environmental system has continued to decline.

Western Australia's wealth distribution is more equal than other Australian states and this may be correlated to indicators of social functionality. Wealth inequality in Western Australia is "visibly" low as many of the very top beneficiaries of the Western Australian economy live outside the state. The case of Western Australia is a good example that shows that changing wealth distribution can lead to loss of functionality from the social perspective even when the economy is at record growth rates and low in unemployment.

The mineral industry system, although fully functional from an economic perspective using standard measures such as GDP growth and employment rates, is less diversified than it was 20 years ago. Declines in agriculture, education and finance as a proportion of economic activity have occurred as the mineral system reached full functionality. This means that the state is becoming more reliant on the mineral industry and less resilient to external shocks (including large price increases or decreases). During the same period the environmental and social systems have declined, most likely due to the flow of resource wealth out of the state and changes to income distribution patterns that have favoured the top 1% of income earners. Innovation, as measured by patents filed per capita, has also decreased during the same period. Norway which has similarly high mineral sales, by way of comparison, has managed to increase its innovation rate during the same period of high commodity prices.

Saving a proportion of mineral export revenue in a state fund that receives revenue from mineral sales in proportion to commodity prices (similar to how a progressive income tax structure works, and similar to Norway's sovereign wealth fund), that promotes long term social, educational and environmental initiatives would improve sustainability from all wealth level perspectives. Under our model, a contribution of 5% of mineral exports to a West Australian wealth fund was shown to increase the functionality from the social perspective by 18 to 25%.

To further explain and understand the impact of wealth inequity on the sustainable development of society, more data needs to be gathered on the wealthiest 1%, as well as those with negative wealth (net debt) who are not measured (regularly) by the Australian Bureau of Statistics. In this study the political aspects of including a wealth fund modelled on Norway's petroleum fund has not been reviewed. Finally, the paper shows that the ISF methodology can be applied to countries, states or regions to measure risk in wealth inequity, and show changes (and potential solutions) that may otherwise not have a framework to be investigated or assessed.

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Notes

Note 1. 2007 numbers calculated using World Bank and ABS Cat. No. 1383.0 (Measures of Australia's Progress) data with an AUD/USD exchange rate of 0.90.

Note 2. Countries with small populations that are used as tax havens such as Luxembourg and Lichtenstein are not included.

Note 3. The largest exporters of state resources include BHP Billiton, Rio Tinto and Shell.

Note 4. P80 is defined as the mean wealth of the 4th highest quintile, and P20 as the mean wealth of the lowest quintile. Strictly speaking it should be P70/P10 but the upper end quintile incomes are unavailable, and the implications for discussion purposes are the same.

Note 5. A number of indices such as the Happy Planet Index and Gross Production Index can also be used to assess sustainability of regions, however in this research using these indices would have necessitated using significantly more data to be inferred from national statistics.

Note 6. Formerly ARMS (Aquatic Real-time Management System) developed by the Centre for Water Research calculates the ISF using raw data and is used to show time series changes in systems, perspectives and functions.

Note 7. $68 billion worth of resource sales were made in 2008 and the population was about 2.1 million (ABS, 2009). It was estimated that company EBITDA was 35% of sales, salaries totalled $9 billion (Rio Tinto, 2008); federal taxes were 30% of EBITDA, suppliers were 20 – 60% local and received $26 billion; WA royalties were $3.35 billion (DTF, 2009).

Note 8. In 2008 Western Australian exports were $68 billion and imports $27 billion (Australian Bureau of Statistics).

Note 9. Calculations made from Business Review Weekly data, “Australia’s top 1000 enterprises”, December 2008.

Note 10. Only one company (Wesfarmers) had its head office in Western Australia among the top 50 largest Australian companies by revenue in 2008 (BRW, 2008).

Note 11. Out of the largest exporters of state resources include BHP, Rio Tinto, Shell and Chevron, BHP has three of its 12 executive board members residing in Australia, and none in WA. Similarly Shell and Chevron have no WA residents as board members, and Rio Tinto has one.

Note 12. Norway is the world's sixth largest exporter of oil and third largest exporter of gas (EIA, 2009). Norway exported US $68 billion worth of oil in 2008 (EIA, 2009) while WA exported $US 65 billion worth of minerals (mostly iron ore) in the same year.

Note 13. The Norwegian sovereign wealth fund had US $450 billion in assets as of Sept, 2009.

Note 14. The WA Commodity Price Index (WACPI) can move 20% in one year as seen in Ye (2008).

Note 15. Numerous price indices track daily prices for commodities including iron ore. WA could receive, for example, an additional 1% of revenue contribution into a wealth fund when iron ore price is is $61-$70/ton, 2% at $71-$70... 10% at $160 or more per ton etc.

Table 1. Wealth inequity of Australian states in 2004 (latest). (ABS Cat. No. 6530.0)

State	P80/20 Ratio	P90/10 Ratio	Mean Wealth	GSP per Capita
Western Australia (WA)	19.18 (lowest)	53.92 (3rd lowest)	$418,389 (3rd)	$59,087 (highest)
Victoria (VIC)	19.70	58.70	$484,474	$46,078
Queensland (QLD)	20.08	54.97	$407,327	$43,711
Tasmania (TAS)	20.16	45.39	$328,019	$38,595
New South Wales (NSW)	20.34	56.49	$564,879	$45,877
South Australia (SA)	20.59	49.34	$357,911	$41,930

In 2004 WA had the most equitable distribution of wealth among Australian states. WA also has the highest GSP per capita (by 28%) and yet the mean wealth is 35% less than NSW.

Table 2. ISF Systems / Perspectives matrix. See Appendix B for details of the indicators (I_i) that make up the functions (F_i).

System K_i Perspective J_i	Social (K_1) Functions F_i are to provide:	Terrestrial (K_2)	Water (K_3)	Minerals Industry (K_4)
Wealthiest (J_1)	*F_1. A feeling of security* *F_2. Provide fulfilment* *F_3. Provide housing* *F_4. Quality healthcare* *F_5. Roads clear of congestion*	*F_{12}. Provide clean air* *F_{13}. Provide accommodation* *F_{14}. Provide natural resources* *F_{15}. Provide renewable energy* *F_{16}. Provide food*	*F_{17}. Maintain clean ground water* *F_{18}. Provide low cost drinking water*	*F_{19}. Provide a return on assets*
Poorest (J_2)	*F_1,F_2,F_3,F_4 &* *F_6. Provide public transport*	*F_{12},F_{13},F_{14},F_{15} & F_{16}*	*F_{17} & F_{18}*	*F_{20}. Provide employment*
Average Wealth (J_3)	*F_1,F_2,F_3,F_4,F5,F_6*	*F_{12},F_{13},F_{14}, F_{15}& F_{16}*	*F_{17} & F_{18}*	*F_{20}*
Environmental (J_4)	*F_7. Use renewable energy* *F_8. Provide protection of land* *F_9. Provide protection of water resources from pollution*			*F_8. Provide protection of land* *F_9. Provide protection of water resources from pollution*
Economic (J_5)	*F_{10}. Provide a growing economy* *F_{11}. Make productive use of human capital*			*F_{19}. Provide a return on assets* *F_{20}. Provide employment*

Table 3. System Weightings (W_i), Google Trends (http://www.google.com/trends)

System (search term)	Google Trends Result for WA	ISF System Weighting (W_i)
Water (water) (W_1)	1.38	0.375
Social System (people) (W_2)	1.00	0.272
Terrestrial Environment (land) (W_3)	0.68	0.185
Minerals Industry (mining) (W_4)	0.62	0.169
Total:	4.74	1.000

Results recorded October 5, 2009. Google Trends (www.google.com/trends) was first used to predict outbreaks of flu across states and regions around the world based on search results (Ginsberg et al., 2009).

Table 4. West Australian economic activity by sector in percentage terms (ABS Cat. No. 5220.0)

Year	Agriculture	Mining	Manufacturing	Education	Finance
1990	4.51	26.79	7.97	4.30	5.17
2008	2.46	29.82	8.49	2.64	4.11
Change	-2.05	3.03	0.52	-1.66	-1.06

The reduction in non-mining sectors of the WA economy will lead to power erosion over time for non-mineral sectors and potential instability caused by reliance on one source of revenue.

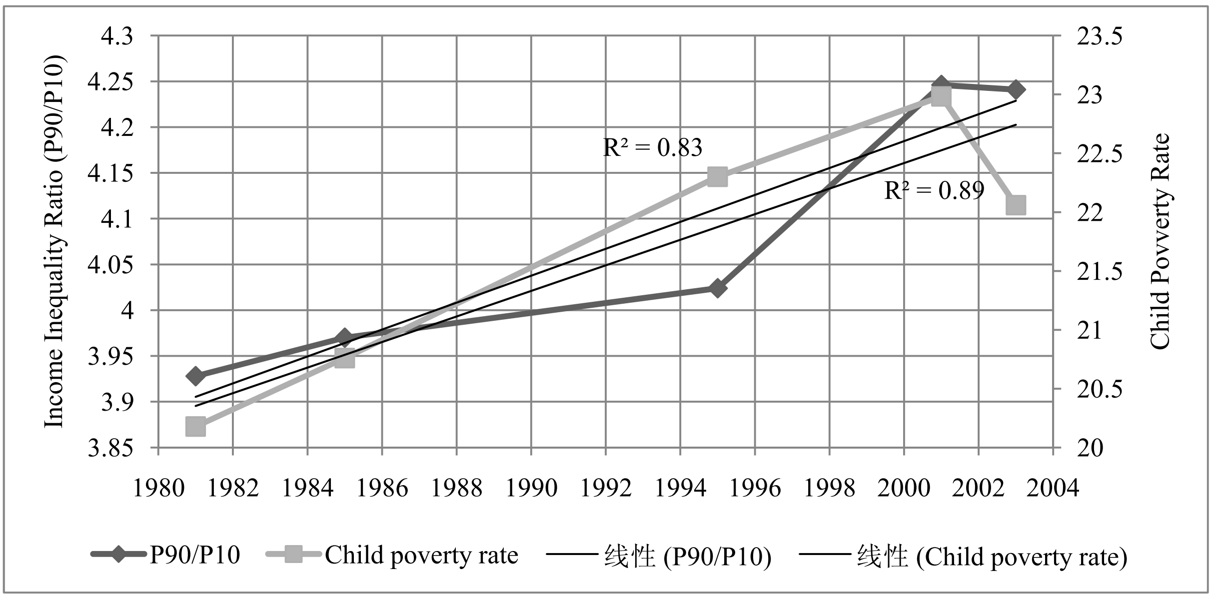


Figure 1. Changes in income inequality (P90/P10) and relative child poverty in Australia (LIS, 2009)

STEP 1: Define the Domain

The domain, D, is the geographic entity under consideration, with N sub-domains

STEP 2: Define the Systems and Perspectives

Systems, K, are collections of processes organized to accomplish specific functions; whilst perspectives, J, are viewpoints or stakeholders. Collectively they comprise the matrix approach to measuring sustainability

STEP 3: Define the Functions

Functions, F, are actions of a system that provide services to a particular perspective

STEP 4: Define the Indicators

The indicators, I, are the datasets which quantify the functionality of each function (or which capture the changes in sustainability over time)

STEP 5: Data Normalisation

Normalisation sets the indicator values between zero and one so that they can be compared and aggregated

STEP 6: Weighting and Aggregation

The weightings, W, reflect the importance of the different elements of the fundamental matrix acrosss all stakeholders. The final values are then averaged to form the final ISF

Figure 2. Process for calculating the Index of Sustainable Functionality (ISF)

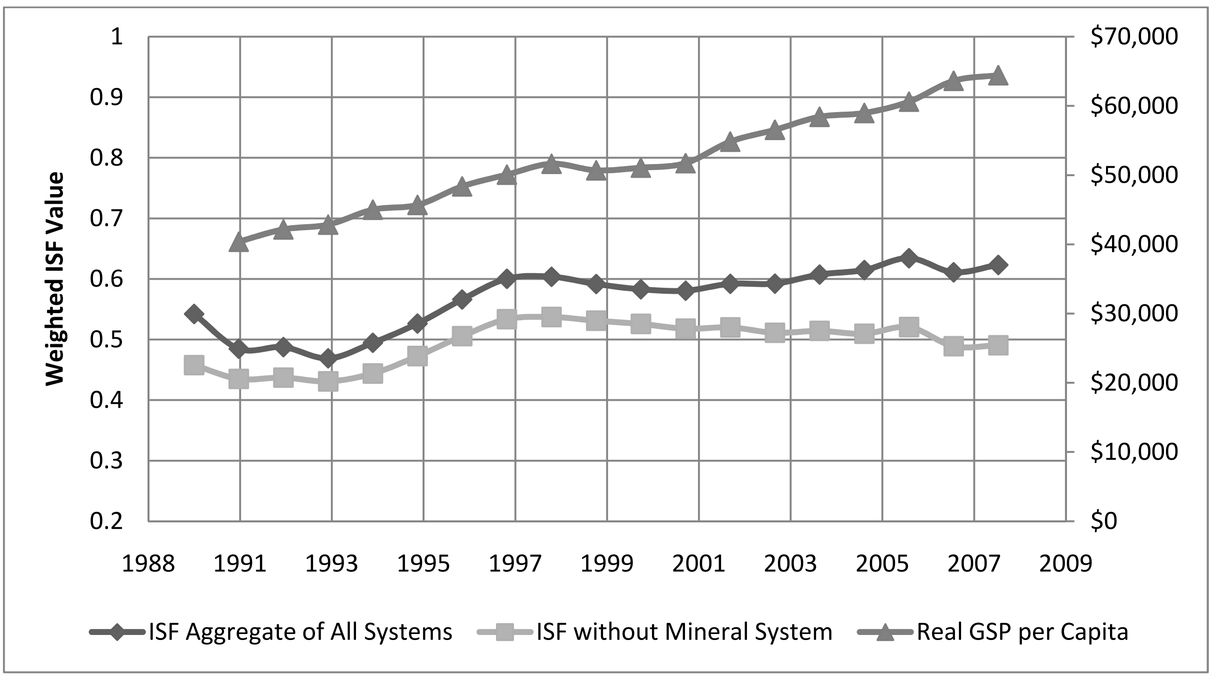


Figure 3. Total ISF with and without the mineral system compared to real Gross State Product per capita (in 1990 dollars) versus time.

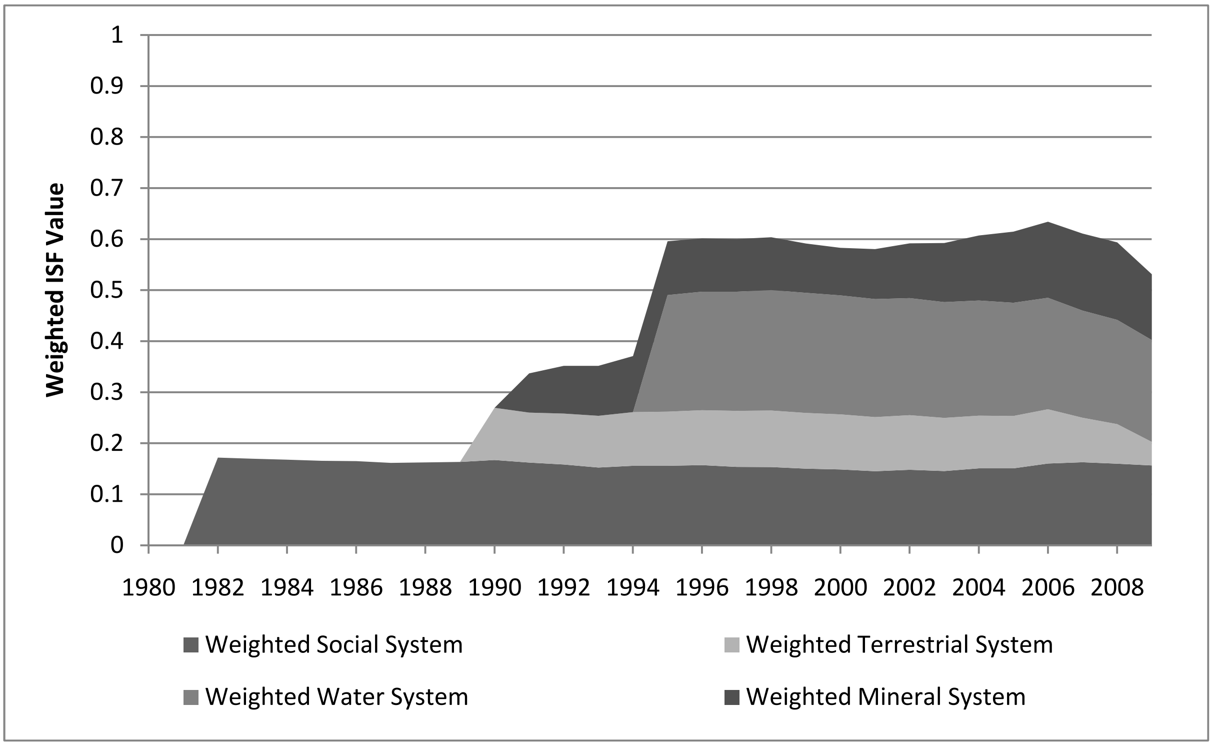


Figure 4. Contribution to the WA ISF from each system; before 1996 data was not available for all systems. System weightings were made according to Table 3.

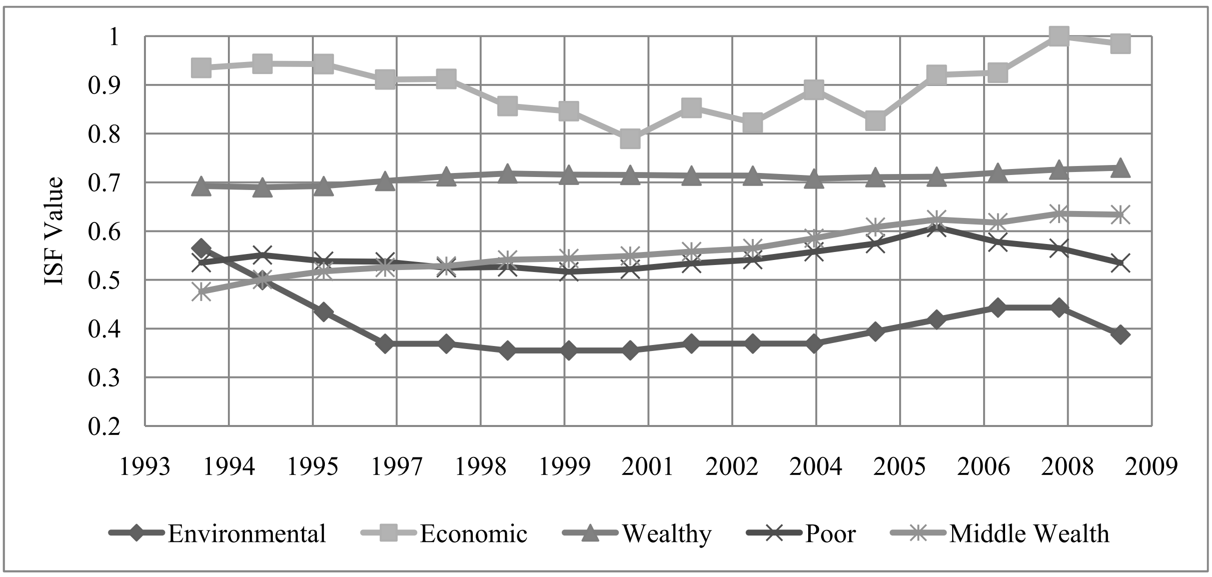


Figure 5. The raw ISF of all systems, from different perspective without weightings, showing that the high value for the economics (grey squares) is closely linked to the ISF viewed from a wealthy perspective (dark grey triangles)

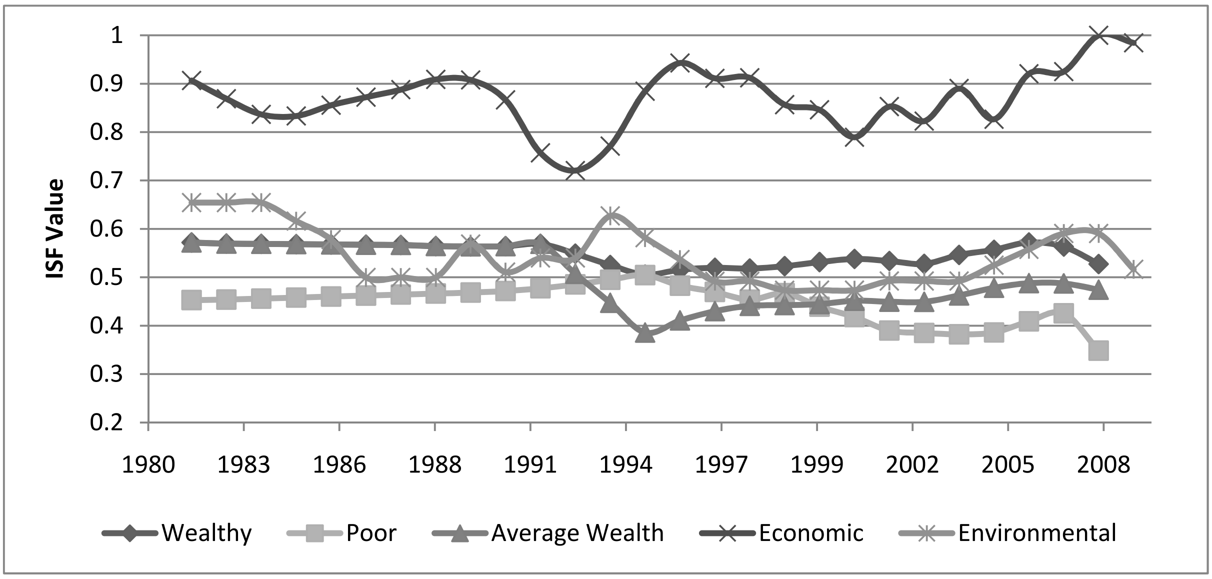
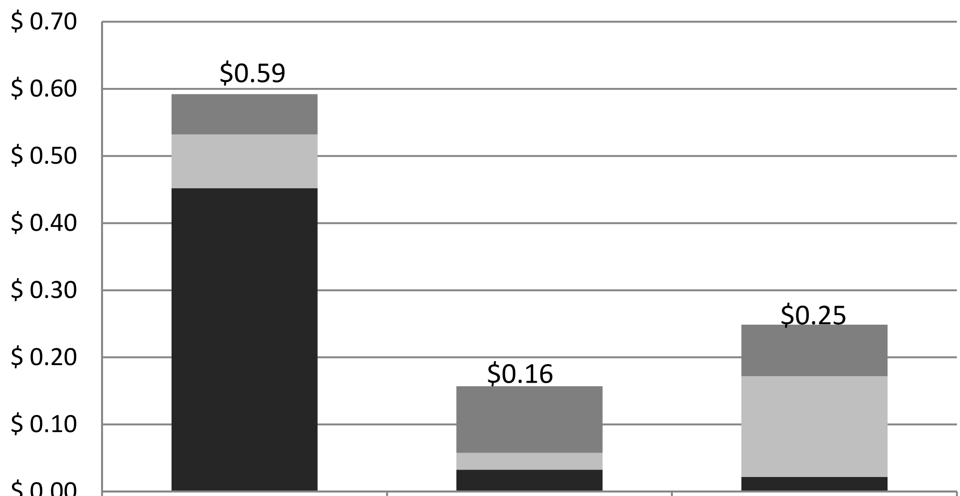


Figure 6. The ISF of the Social System from different perspectives; from 1991 onwards there is a clear separation between the functionality of the social system from a perspective of the wealthy (reasonable at 0.5), to the middle class (below satisfactory at 0.43) to that of the poor down to 0.36 by 2008.



	International	Australia (not inc. WA)	Western Australia (WA)
Government Revenue	$0.06	$0.10	$0.08
Salaries	$0.08	$0.02	$0.15
Shareholders	$0.45	$0.03	$0.02

Figure 7. Destination per dollar of mineral revenue (including oil & gas) for 2007-2008 financial year (period of high commodity prices). Estimates based on annual reports (BHP, 2008; Rio Tinto 2008) and WA Government Department of Treasury and Finance reports (2009). An error margin of approximately ±10% exists in these estimates. Capital investment is considered part of local spending. See Note 7.

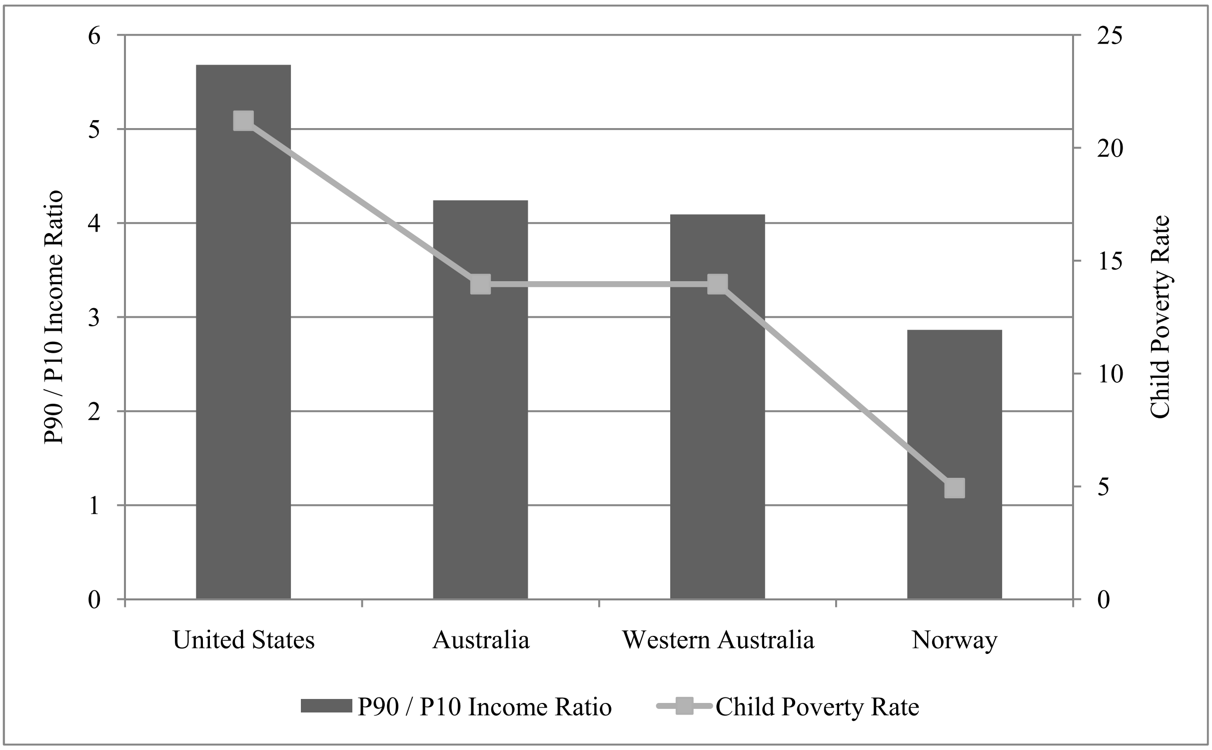
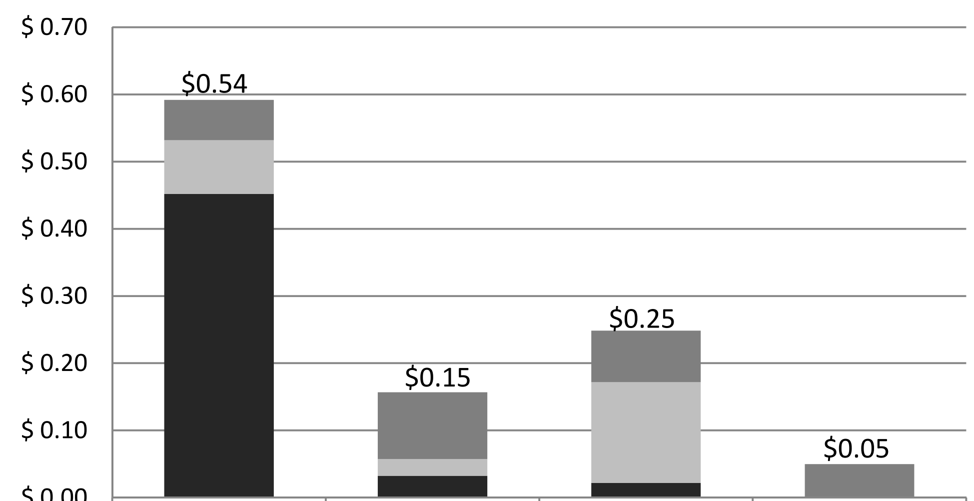


Figure 8. Comparison of Income Inequality and Child Poverty Rates between Western Australia, Australia, Norway and the United States of America in 2003 (LIS, 2009; ABS 6523.0, 2004)



	International	Australia (not inc. WA)	Western Australia (WA)	WA Wealth Fund
Government Revenue	$0.06	$0.10	$0.08	$0.05
Salaries	$0.08	$0.02	$0.15	
Shareholders	$0.45	$0.03	$0.02	

Figure 9. Approximate destination of $1 in mineral revenue with the introduction of a 5% contribution to a wealth fund in WA (2008 dollars). Assumes no change in investment decision or production decision making.

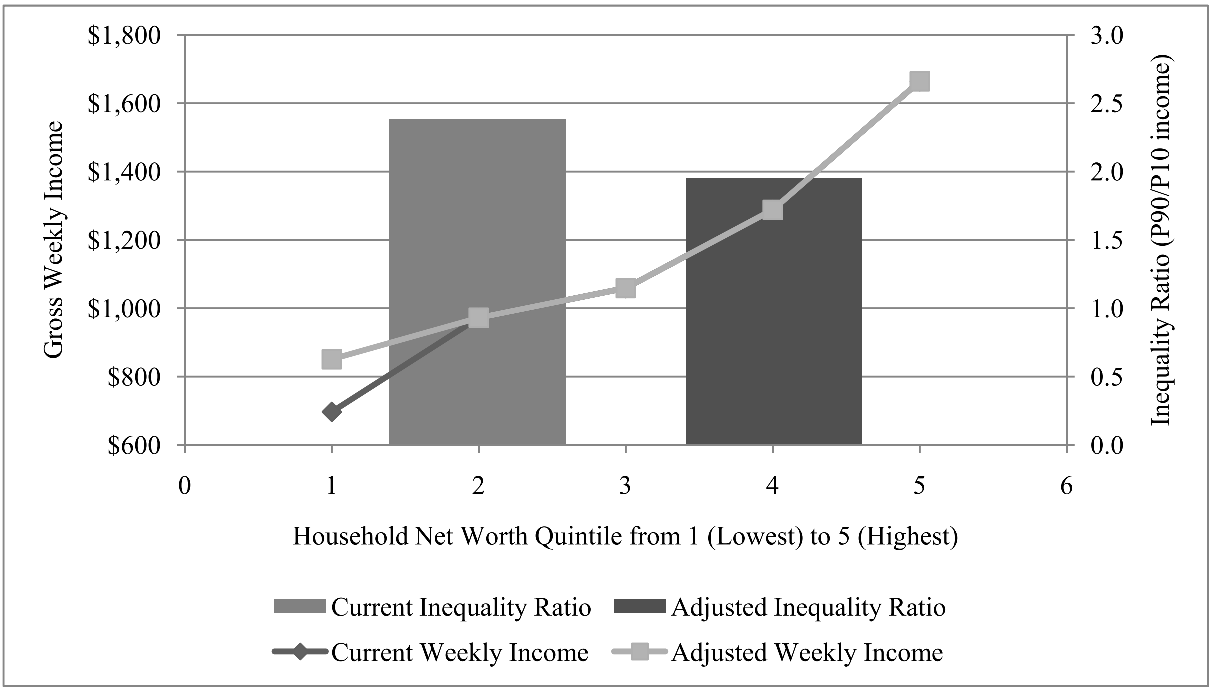


Figure 10. Gross weekly income for WA net worth quintiles if a 5% mineral revenue contribution was provided directly to the lowest net worth quintile

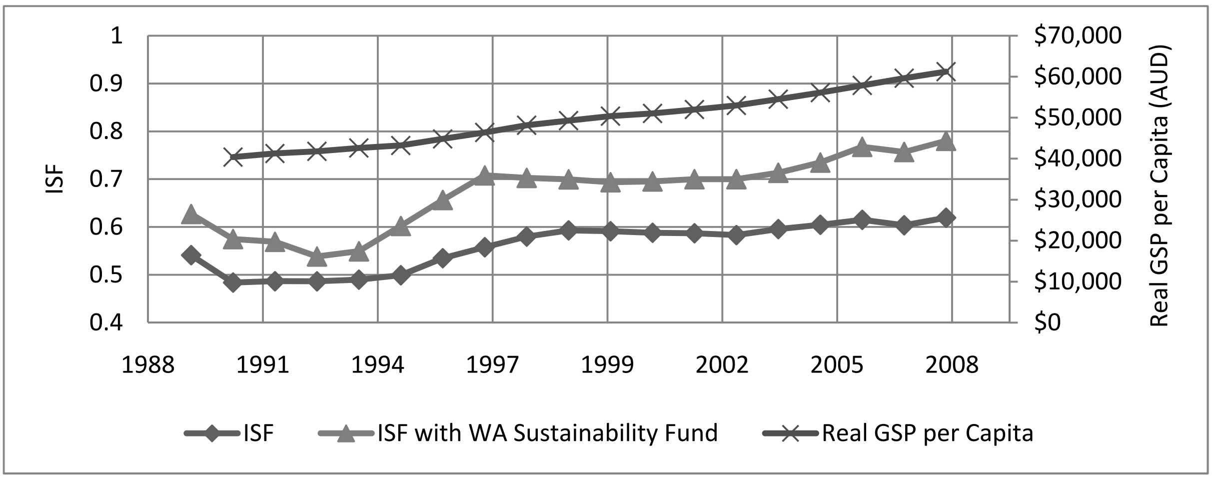


Figure 11. ISF with introduction of WA sustainability fund contributing to the poorest 20%, environment and infrastructure

Appendices

Appendix A. Definition of terms

Adaptive Sustainability: Adaptive refers to introduction of feedback that changes the functionality of that system with the goal of improving the sustainability of the domain.

Controllable Driver: A controllable driver is a first order function that causes changes to the domain as measured by an indicator and is able to be changed through direct human intervention, for example through a policy change.

Domain: The geographic entity under consideration.

Functionality: Functionality refers to the performance of a system in relation to its reason for being and quantified as such either in aggregate or from a particular perspective, where "0" is "dysfunctional" and "1" is functional or "fully functional".

Inequality (interchanged with inequity where it reads better): The unequal distribution of household or individual income or wealth across residents of a state. Income inequality can be presented as a ratio of highest to lowest income or wealth among quintiles of residents (e.g. P80/P20) or deciles (e.g. P90/P10); or as an index.

Net Present Value (NPV): The value of a dollar today compared with the value of that same dollar in the future, after taking inflation and returns into account.

Perspectives: Perspectives relate the functioning of a system from the view of an observer. The wealthiest are the 20% of households that have the most wealth as defined by their assets in monetary terms with mean income at P90; the poorest are the 20% of households that own the least assets with mean income at P10; the average wealth households that are in the mid three quintiles of household wealth measured as mean wealth and have an expected mean income at P50 level; the Environmental perspective is that of native plants and animals whose goal is survival, reproduction and protection from pollution; and the economic perspective is that which includes productive capacity and power as measured by GSP and employment.

Real Gross State Product: Inflation-adjusted measure that reflects the value of all goods and services produced in a given year.

Revenue: Gross revenue after royalty payments unless otherwise noted.

Systems: Systems are a collection of processes that we aggregate for the purposes of measuring sustainability. The social system incorporates human interactions and man-made functions; the terrestrial environment system includes land which provides shelter, water, food and other natural resources; the water environment system is the aquatic includes ground and surface water; and the Mineral Industry system is the largest industry in Western Australia which includes oil and gas, iron ore and other mineral production and processing.

Triple Bottom Line: the triple bottom line refers to the importance of the economy, environment and social aspects that together represent sustainability.

Appendix B. List of functions and indicators

Function (F_i)	Indicators (I_i) corresponding to Function
(F_1) To provide a feeling of security	Break and enter rate (I_1); proportion of people faced with blackmail or extortion (I_2). Crime data was obtained from Australian Bureau of Statistics (ABS) Category Number (Cat. No.) 4102.0 (Australian Social Trends). Data was normalised using a lower bound for a functional blackmail and extortion rate of 1 per 100,000 people which was bettered four times between 1993 and 2007 (when data was available). The upper bound was 5 per 100,000 which was exceeded only once between 1992 and 2007. The lower bound for unlawful entries was 20 per 1000 people (bettered twice between 1993 and 2007) and the upper bound 50 per 1000.
(F_2) To provide fulfilment	Suicide rate across society (I_3). Suicide rate data was obtained from ABS Cat. No. 3302.0 (Deaths) and the lower bound set at 5 per 100,000 people and an upper bound of 20 per 100,000 people. The choice of bounds was based on 14 countries having suicide rates higher than 20 per 100,000; and 10 countries having a rate less than 2 per 100,000 (according to the World Health Organisation). From the poorest perspective, another indicator of fulfilment was included with equal waiting to suicides. This indicator was the waiting time for public housing (I_4) with a functional bound of 20 weeks and a dysfunctional bound of 50 weeks. Data was taken from the Government of Western Australia State Homelessness Strategy, and ABS Homeless Survey 2001.

(F_3) To provide housing	Change in cost of housing relative to mean income of top; middle and bottom wealth quintiles (I_5). House prices were obtained from ABS 6416.0 and Real Estate Institute of Australia (REIA) data. The functional bound was set at annual mean income equal to twice annual house prices. The dysfunctional bound was set at house prices 20 times higher than mean income. Mean income data was taken from ABS category 6523.0 quarterly publications. The fully functional (I=1) condition was set at annual income equalling average house price, and the dysfunctional (I=0) bound was where the average cost of housing was 20 times higher than the annual income.
(F_4) To provide quality healthcare	Infant mortality rate (I_6). The source of data was ABS Cat. No. 3302.0 (Deaths, Australia). Data was provided for 1980, 1990, 2000 and 2006 (filled in with straight line series between each data point). The functional bound was where the infant mortality rate was 0 per 1000 and the dysfunctional bound was 20 per 1000 (approximate to the highest OECD figure and allowed for a robust time-series comparison).
(F_5) To have roads clear of congestion and easily move around	From the perspective of the wealthy that are more likely to drive cars, the greater public transport use the less traffic is on the roads. The measure of road congestion is therefore based on the annual public transport trips per capita (I_7). Data was sourced from ABS 4605.0 (1997) for 1971, 1981, 1991 data; and the Public Transport Authority (2008) Annual Report for 2007 and 2008. The functional condition was set at 100 trips per capita per year; and the lower bound at 25. In 1970 the condition was fully functional, but since this time there has been a slow and steady decline in the rate that reached 49 in 2007. In 2009 there was a slight increase to 49.7, most likely as a result of a new train line, however this still is less than half the rate of 40 years prior and therefore less than a functional condition.
(F_6) To provide public transport	This indicator (I_7) uses the same data and bounds as F_5, however from the poor perspective that may not have the same car availability. This might be a simplistic analysis as the rate of public transport use may be declining overall because the lowest socioeconomic group may be able to afford cars. Nevertheless the indicator is still relevant as in this case, greater public transport use would benefit this group for the same reasons as the wealthy. Again this indicator has shown a steady decline to below 50% functionality.
(F_7) To provide efficient use of energy resources	This function aggregates the energy generated by industry per unit of GSP (I_8) with the renewable energy use as a fraction of overall energy used (I_9). Energy use data was published by the Australian Bureau of Agriculture and Resource Economics (ABARE). GSP data was published by the ABS (Cat. No. 5520.0). The bounds for renewable energy use were set at 0% (dysfunctional) and 5% (fully functional) in accordance with an exponential increase to the 2020 target of 20% renewable energy use.
(F_8) Provide protection of land	Data was sourced from ABS Cat. No. 1367.5 (West Australian Statistical Indicators). No annual change in the area affected by dry land salinity (I_{11}) was considered functional and an increase in dry-land salinity of 5% dysfunctional.
(F_9) Provide protection of water	The number of oil spills (I_{12}) and the volume of oil spilt (I_{13}) per annum were aggregated to provide one of the two equally weighted indicators. Having no spills was considered functional and 3 spills dysfunctional. Spill volumes of less than 1,000 litres were considered functional (=1) and greater than 20,000 litres dysfunctional (=0). Data was provided by the Australian Maritime Safety Authority.
(F_{10}) Provide a growing economy	Economic growth was measured as annual change in real GSP per capita (I_{14}). The dysfunctional bound was set at -5% growth (contraction) and fully functional bound at 3% increase. Data was provided by ABS Cat. No. 5220.0 (State Accounts).
(F_{11}) Make productive use of human capital	The productive use of human capital is represented by the unemployment rate (I_{15}). The dysfunctional bound was set at 30% unemployment; and the functional at 4% unemployment. Data was provided by ABS Cat. No. 6202.0 (Labour Statistics).
(F_{12}) Provide clean air	All members of society benefit from clean air and a stable climate. Clean air was calculated using absolute production of CO2-e (I_{16}). Data was sourced from ABS 4613 (Australia's Environment: Issues and Trends). The fully functional bound for WA was

	set at 50 million tons (mt) CO2-e per annum (1980 level) and the dysfunctional bound at 200 mt per annum. In 2006 WA reached 70 mt per annum.
(F_{13}) Provide accommodation	The purpose of the terrestrial environment from the perspective of all wealth levels in society is to provide shelter and the indicator chosen was the ratio of income to house prices (I_{17}). The ability to afford housing is a measure of the terrestrial environments functionality in that respect. For the wealthiest, mid-wealth and poorest in society, the respective disposable income was sourced from ABS 1383.0 (Measures of Australia's Progress). House prices were sourced from ABS 6416.0 (House Price Indexes) for 1990 to 2009 and REIA data for 1970-1989. The functional bound was set at the average house price 2 times the annual disposable income; and dysfunctional bound set at 20 times the annual disposable income. These bounds were chosen based on historical data.
(F_{14}) Provide natural resources.	The terrestrial environments ability to provide natural resources is a measure of its functionality from the perspective of all society. For the wealthy in WA mining is also a generator of income. Data for the percent of the economy derived from mining income (I_{18}) was sourced from ABS 5220.0 (State Accounts). As WA is a globally significant mining region10% was the dysfunctional bound and 30% was the functional bound. Above 30% reduced the functionality as this level was deemed very high historically and reduced the ability for other terrestrial industries (such as agriculture) to function effectively.
(F_{15}) Provide renewable energy.	The bounds for renewable energy as a percentage of overall energy use (I_{19}) were set at 0% (dysfunctional) and 5% (fully functional) in accordance with an exponential increase to the 2020 target of 20% renewable energy use. Data was sourced from ABARE Energy 2009.
(F_{16}) Provide food	The provision of food is an important terrestrial function. The fully functional condition was set at 5% agriculture, forestry and fishing production as a proportion of total economic activity (I_{20}). 1% was the dysfunctional bound. Data was sourced from ABS 5520.0 (State Accounts).
(F_{17}) Maintain clean ground water	Maintaining clean ground water is fundamental to the water system for the health of all members of society. Levels of arsenic (I_{21}) and the pH of ground water (I_{22}) in the northern suburbs of Perth were selected as indicators. The functional bounds for arsenic was 0.1 parts per million (ppm) and the dysfunctional bound 0.5 ppm. The functional pH levels were between 6 and 8; and the dysfunctional less than 3 or greater than 10. Data was sourced from Appleyard et al. (2006).
(F_{18}) Provide low cost drinking water	Low cost (and safe) drinking water is vital for the health and well-being of all society. The absolute cost of water (per kL) (I_{23}) and cost of water (per kL) relative to disposable income (I_{24}) were used to calculate the functionality from each wealth level perspective. For the absolute cost, the functional bound was set at less than \$0.50 per kL (~cost of supply) and the dysfunctional bound \$5 per kL (order of magnitude greater). The functional bound relative to disposable income was set at 2% of annual disposable income; and the dysfunctional bound set at 10% of disposable income. These levels were chosen based on historical ranges and expected problems in a society for those that spend more than 10% of disposable income on a basic need such as water. Water prices were sourced from DFT (2009) and ERA (2007).
(F_{19}) Provide a return on investment for mineral assets	From the perspective of the wealthy, mineral assets in WA provide income. As WA is a commodity based economy, returns were estimated using the Dow Jones Commodities Index (I_{25}). Index values ranged between a low of 87 in 1999 and 172 in 2007. The dysfunctional bound was set at 50; and the functional bound at 150. Data was sourced from Reuters and an annual average was used.
(F_{20}) Provide employment	The WA mineral industry employs approximately 75,000 people out of 1,112,000 workers (ABS 1367.5; 2008). For the mid-level wealth and poorest members of society, the industry provides work. The number of people employed by the minerals industry as a percentage of total employment (I_{26}) was used in this indicator. Data was sourced from ABS Cat. No. 1367.5 (WA Statistical Indicators). The dysfunctional bound was 1% of state employees, and the functional bound 2.5%.

Appendix C. Controllable drivers for ISF with WA (wealth) fund

Controllable driver (Cd_i) with corresponding function (F_i) and (System/Perspective)	Description (to be read in conjunction with Appendix B)
Cd_1. Waiting time for public housing (F_2) (Social / Poorest)	Waiting time for public housing forms half of the function to provide fulfilment. The dysfunctional bound was changed to 100 weeks instead of 50 weeks in order to represent a 50% improvement in indicator performance (i.e. halving the waiting time for public housing for the poor). Cd_1 is considered only from the perspective of the poorest 20%.
Cd2. Affordable housing (F_3) (Social / Poorest)	Affordable housing is the driver of the function to provide affordable housing. The functional bound was changed from 20x annual income to 10x annual income to represent a combined increased 50% disposable income and public housing for the poorest; and the flow on effects with greater supply of housing to the mid-level (P50) society.
Cd3. Public transport (F_6) (Social / Poorest)	The use of public transport in WA has dropped from 97 trips per year in 1970 to less than 50 in 2008. The functional bound was changed to 50 from 150 to represent the improvement to the poor by increasing access to public transport by two thirds. No changes were made to the other perspectives even though positive impacts would be felt from reduced traffic congestion and additional public transport access for all.
Cd_4. Renewable energy F_{15} (Social/Environment), (Terrestrial/Wealthy, Mid, Poor)	The proportion of renewable energy used forms half of the function to make efficient use of energy. The use of renewable energy was doubled while the energy use generated by industry per GSP was unchanged.
Cd_5. Water protection (F_9) (Social / Environment) (Minerals / Environment)	The protection of water was adjusted using the controllable driver of more stringent regulations and practices with regards to oil spills. The dysfunctional bound was increased to 6 oil spills per year (from 3) and the volume increased to 40,000 (from 20,000) litres to calculate the impact of halving the occurrence and impact of oil spills.
Cd_6. Greenhouse gas emissions (F_{12}) (Terrestrial/Poor, Mid, Wealthy)	The impact of CO2 emissions will be felt by all (including the wealthy with houses near the WA coast) through increased insurance and environmental costs. The net greenhouse emissions bounds were changed from 200 (MtCo2-e) to 400 to represent reducing (or offsetting) half of WA emissions.
Cd_7. Agriculture, forestry and fishing as percentage of industry (F_{16}) (Terrestrial/Poor, Mid, Wealthy)	Increasing the proportion of business based upon improved renewable natural resources such as agriculture, forestry and fishing (over the long term) through environmental improvements such as re-forestation, water quality improvements and aquaculture would improve the terrestrial environment's ability to produce food. This is represented in the change of bounds (F_{16}) to double the output.
Cd_8. Clean ground water (F_{17}) (Water / Poor, Mid, Wealthy)	The bounds for pH and arsenic were changed by 10% to reflect the ISF result of reducing pollutants in ground water in the Perth area.
Cd_9. Price of water (F_{18}) (Water/Poor, Mid, Wealthy)	The bounds for the price of water relative to income and absolute price was changed by 50% to reflect a 50% reduction in price for all members of society.