FLYING 'BLIND' OR 'FULLY SIGHTED' IN THE DESIGN OF URBAN SYSTEMS?

A "Physical System's" Response to Peter Newman's:

SUSTAINABILITY ASSESSMENT AND URBAN SYSTEMS

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ABSTRACT
Urban systems are the location where, and the reason why, most of Australia's ever growing consumption activities take place. This response to Peter Newman's paper makes five points as follows: Firstly, the sustainability of physical systems in the long run is the essential precursor to social and financial sustainability. Without physical sustainability, society cannot embrace social and financial sustainability. Secondly, in a life cycle context that includes both the direct and indirect effects of consumption, the per capita requirements for energy, water and land are directly related to per capita discretionary expenditure. Most urban sustainability policies target the smaller 'direct' effects, while ignoring the much larger 'indirect' effects of the full production chain. Thirdly, many well developed sustainability approaches such as 'stories and indicators' will be helped in meeting physical sustainability goals if they are immersed in 'whole city' analytical frameworks that can test the physical feasibility of societal aspirations over the next century. Fourthly, six physical sustainability principles are proposed which cover stabilising human population, reducing use of key elements, basing the economy on flows, shortening the supply chain, engineering a durable society and designing taxation systems that 'tell the truth'. Finally, the conclusions assert that some sustainability aspirations are 'flying blind' in intergenerational terms because of their lack of physical reality and rigour. This leads citizens and their elected leaders to think 'they can have their cake and eat it too' and perhaps even 'that the cake is getting bigger'. These may be unfortunate perspectives if the lucky country expects to stay lucky.

THE ANALYST'S PERSPECTIVE
This response to Peter Newman's position paper, "Sustainability Assessment and Urban Systems" will support his positions and directions and will focus primarily on five aspects of sustainability of the physical transactions that underpin the much broader canvas he describes. The first issue is one of primacy and feasibility. The 'physical economy' view is that the ever growing physical transactions that underpin the function of the modern economy are the essential challenge to sustainability in the long run. Most sustainability analyses avoid this unpleasant fact or at best do not have the data and tools to analyse it properly. Unless this issue is resolved, modern growth economies may collapse under their own weight and waste. Secondly, this physical viewpoint will be used to elaborate on the sustainability assessment criteria for Western Australia[1]. Thirdly, a new method of whole economy 'triple bottom line' analysis will highlight some potential issues for the three assessment scales[2] with which sustainability governance may have to deal. The fourth point is

[1] Table 2 in Peter Newman's position paper.
[2] In Peter Newman's paper (page 1) the three types are (1) 'policies, programs and plans', (2) 'complex and strategic projects' and (3) 'buildings and developments'.

that many of the issues must come into confluence in a numerate rigorous framework of analysis where policies can be tested, and city function designed well ahead of the first sod being turned. Finally six principles of physical sustainability are proposed to sit under and supplement the higher level 'Foundation Principles' developed for Western Australia.

The impasse between modern consumption driven economies and physical sustainability is clearly articulated in Figure 1. This shows the relationship between per capita spending and the amount of primary energy required to allow this volume and pattern of consumption to occur. This is essentially a life cycle analysis of the consumption patterns expressed in energy terms for several thousand households in Sydney. Three issues challenge the sustainability analyst. The first is that direct energy costs, the electricity and gas for our homes and the petrol for our cars, increases only slowly across this range of personal consumption patterns. By comparison, the total energy (direct energy use plus indirect energy use embodied in the full production chain) rises much more rapidly. There is a 30 fold difference between the lowest and highest spenders. The third point is that while the energy intensity of personal consumption is 50% lower for each dollar spent by more affluent consumers, this efficiency gain makes little difference to the total energy required i.e. there is little saturation or plateauing effect across the expenditure range.

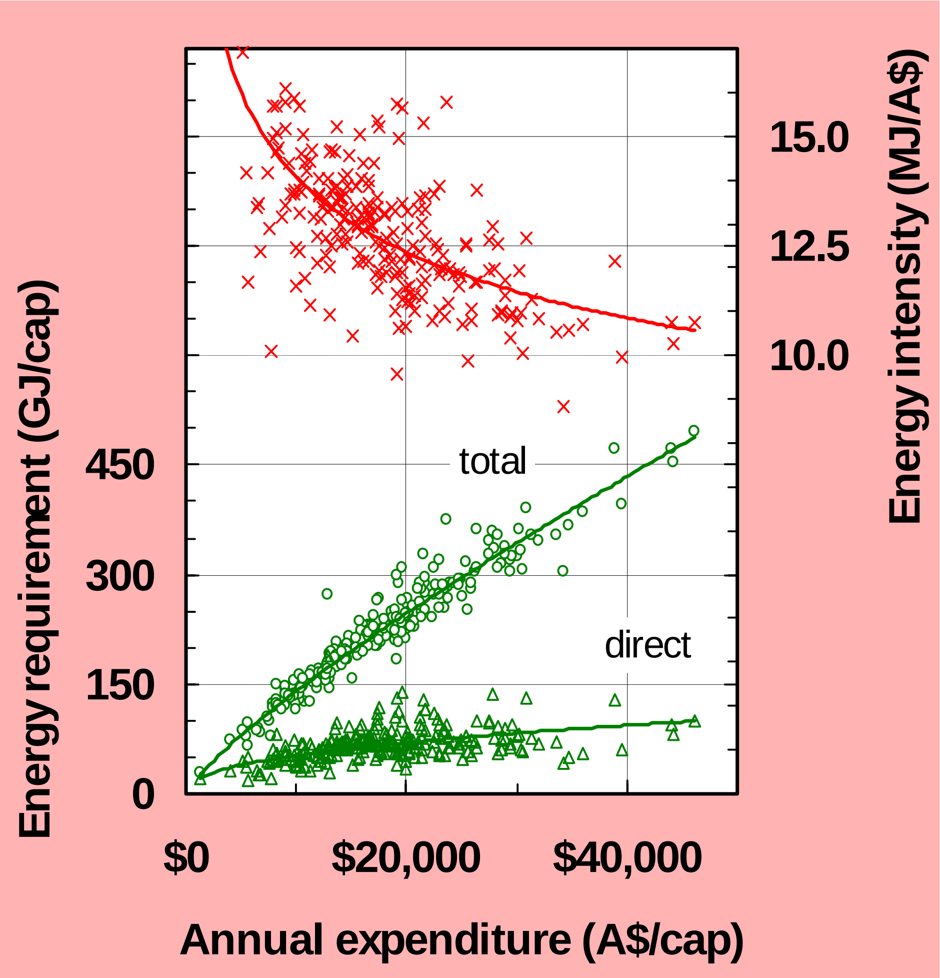

Figure 1. The relationship between per capita discretionary expenditure and the embodied energy in the full life cycle of that expenditure. The figure shows direct requirement (bottom graph), the total requirement for primary energy (middle graph) and the energy intensity (top graph) across the per capita expenditure range collected in the ABS household consumption survey[3].

[3] Lenzen, M., Dey C. and Foran B. (2004). Energy requirements for Sydney households. Ecological Economics 49,375-399.

Inevitably, the current structure of a modern economy propels the individual's lifestyle and spending patterns onto this graph. For each one of us, it is then a normal aspiration that each one of us progress along this graph. As urban population grows, there are more of us doing the same, but why is this a problem? With the current energy infrastructure of the Australian economy, most of the energy is fossil energy and the energy requirement curves translate directly to greenhouse gas emissions. To complete the picture, there are similar relationships for water use and land disturbance. This increasing consumption expenditure drives GDP growth rate and has embodied in the physical resources of energy, water and land. Each dollar of consumption expenditure is underpinned by eight megajoules (10^6 J) of primary energy, one kilogram of greenhouse gas emissions, 40 litres of managed water and three square metres of permanently disturbed land. If technological settings and the structure of the economy remain more or less static, a 3% growth rate in GDP will double the size of the economy every 25 years. By 2050, the physical requirements of economy could be four times the size of today's economy.

Most of this expansion will be driven directly or indirectly by the consumption habits within urban systems, yet they wear few of the consequences. Urban management systems concentrate mostly on the direct effects that grow only slowly across the full range of consumption expenditure. The energy and water efficiency clawbacks mandated by the new BASIX system[4] in New South Wales deal with one fifth of the physical issue, admittedly a good start. However 80% of the energy use issues are left without standards, guidance and controls. In physical reality, the inter-sectoral rebound effect[5] could then increase the amount of energy and water used. The eventual savings of physical inputs and lower bills often migrate to additional consumption activities. Savings made within one module of the urban system (the domestic house or commercial building sectors) stimulate addition energy and water use indirectly in other parts of the economy and even overseas.

Table 1. A structural decomposition analysis of the driving causes of greenhouse gas emissions in the 28 year period from 1969 to 1997, spanning the historical availability of financial input-out tables of the Australian economy.

Accelerating Factors	Industrial Structure +1.0%	Economic Growth +1.5%	Population Growth +1.1%	Export Volume +0.8%	**Total Growth +4.5%**
Braking Factors	Energy Intensity of Industry -1.3%	Fuel Mix -0.3%	Final Demand Mix and Destination -0.4%	Export Mix -0.1%	**Total Growth -2.1%**

In a systemic sense, the knock-on effects of rebound lead to key driving issues of un-sustainability becoming off limits in management terms. This leads to one of the final conclusions in this review of 'focusing on primary drivers rather than proximate ones'. An intricate analysis of the causes of greenhouse emissions over the last 30 years[6] reveals that there were four 'accelerators' of greenhouse emissions and four 'braking' factors (Table 1). The elements in the analysis show the accelerators growing greenhouse emissions at the rate of 4.5% annually, while the braking factors slow emissions at the rate of 2.1% annually, giving a net rate of emissions growth of 2.3% annually (after rounding errors).

Urban sustainability policies aim to implement many of the braking factors such as energy efficiency programs for industry (energy intensity), air emissions controls (fuel mix), sustainable consumption policies (final demand mix and destination) and green export programs (export mix).

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[4] Department of Infrastructure Planning and Natural Resources (2004). What is BASIX? http://www.basix.nsw.gov.au/information/about.jsp#whatisbasix accessed 9-9-2004

[5] Rood, GA; Ros, JPM; Drissen, E; Vringer, K. (2003). A structure of models for future projections of environmental pressure due to consumption. Journal of Cleaner Production. 11,491-498.

[6] Wood R. (2003). The Structural Determinants for Change in Australia's Greenhouse Gas Emissions. Honours Thesis, School of Physics, University of Sydney. Unpublished honours thesis, 148pp.

The first physical reality though is that the accelerating factors outpace the braking factors by a ratio of two to one. The second physical reality is that few urban sustainability strategies could contemplate limiting these accelerating factors of industrial structure, economic growth, population growth and export volume. Instead strategies concentrate on the braking factors and are probably doomed to failure in a systemic sense, since they focus on proximate drivers rather than primary ones. However some urban entities may improve their sustainability bottom line when a smokestack industry closes or moves to another area. Rapid technological advances in geo-sequestration of carbon dioxide may solve the greenhouse issue presented here. While the analyses have not been completed for water use and land disturbance, they are expected to yield similar results where the accelerating factors outrun the braking factors. This leaves the ‘physical reality’ viewpoint on sustainability pressure variables somewhat at odds with the ‘economic reality’ viewpoint.

ASSESSING THE SUSTAINABILITY CRITERIA

The ‘physical economy’ view of Western Australia’s sustainability criteria is essentially neutral for four of the nine criteria (Table 2). The driving rationale for comments on the other five sustainability criteria is the embodiment of energy, water and land in each consumption dollar. However, the world will change and such criteria are developed and implemented to force the re-balancing and de-directing of financial, social and environmental goals. The question remains though, whether such governance processes and the resultant criteria are adventurous and challenging enough to effect the desired rate, and the eventual amount of change.

Table 2. A ‘physical economy’ commentary on the ‘Criteria for Sustainability Assessment’ in the WA Sustainability Strategy” (Newman’s Table 2).

Promoting the Positive (sustainability assessment)	**The ‘Physical Economy’ perspective of sustainability assessment**
Provides both short and long term economic gain.	Economic growth as currently structured in the Australian economy is mostly physical and by definition challenges sustainability.
Increases access, equity and human rights in the provision of material security and effective choices.	Physical economy view is neutral
Improves biodiversity and ecological integrity and builds life support systems.	Economic growth and consumption have high land and water content and pressure on ecological integrity may increase.
Reduces the ecological footprint while improving the quality of life.	Size of the ecological footprint is directly related to consumption expenditure, but large changes in the composition or volume of consumption can halve footprint size.
Builds up community and regions, ‘sense of place’ and heritage protection.	Physical economy view is neutral
Provides conservation benefit and net social-economic benefit.	Physical economy view is neutral
Increases ‘common good’ resources.	Physical economy view is neutral
Ensures there are acceptable levels of risk with adaptation processes for the worst scenarios.	Most adaptation processes treat the symptoms with end of pipe solutions rather than reducing the primary driving causes.
Brings change and a sense of hope for the future as it is linked to a broader strategic vision.	Physical economy view is neutral but notes many growth enhancing strategies rely on increased use of resources

To differ from the first criterion of ‘providing short and long term economic gain’ is politically unacceptable in an economic structure and philosophy that is mostly founded on growth. Yet for the Australian economy, the physical economy view reveals that the last century of development has been paralleled by an exponential rate of increase in the use of primary energy[7], land and water[8]. This does not imply that development has been due solely to these physical inputs, but breaking the trend will require a substantial restructuring of the Australian economy. Currently, these are few indications that restructuring is underway, or even intended. The third criterion of ‘improving biodiversity and ecological integrity’ is also linked to the land and water implications of current economic structure. Within the boundary of an urban system, it is possible to increase native vegetation areas, protect and reconstruct wetlands and so on. However, the implications of Figure 1 also hold true for the land and water content of personal consumption. Thus it is possible to improve natural capital in the urban system’s backyard, while concurrently increasing pressure on land and water resources outside the urban boundary in Australia or in overseas trading partners.

The fourth criterion of ‘reducing the ecological footprint’ is analysed in a later section. The conclusion is that a halving is possible if dietary composition is changed and urban energy systems are restructured. It is difficult to dissent from the eighth criteria of ‘acceptable levels of risk and adaptation processes’ but the difficulty for physical economy analysts is to gain acceptance that the whole economy drivers highlighted in Table 1 have defined risks attached to them. Any negative implications for the ‘accelerators’ are managed by ‘end of pipe’ solutions, or by a counter debate that ‘technology will produce weightless growth in perpetuity’. Finally, the ninth criterion of ‘bringing change and a sense of hope’ is difficult to dissent from. The physical economy viewpoint asserts that because of short term and poorly wrought analyses, society may be systematically misled as to the size and extent of the physical changes required to embrace physical sustainability. Any suggestions of difficult or constrained futures that may challenge the status quo are often met by counter attacks colouring these views and the analyses that underpin them as “Malthusian, Doomsday and Luddite”. This makes it more difficult for the technical and analytical tasks to move forward and gain policy traction.

TRIPLE BOTTOM LINE CHALENGES

The three levels of sustainability assessment (policies, strategic projects, developments) proposed in Newman’s paper can be analyses in a numerate and strategic sense by a method of ‘triple bottom line’ analysis now being developed in a top down and macro-level sense for the Australian economy. Invoking the ‘triple bottom line’ is a ‘Process Principle’ enunciated in Newman’s Table 1. This particular application uses the technique of extended input-output analysis[9] to derive financial indicators (surplus, exports, imports), social indicators (employment, income, government revenue) and environmental indicators (water use, land disturbance, greenhouse emissions, primary energy use) and references them against one consumption dollar in each sector of economic activity. The aim here is to complement the suggested structure by showing how the likely tradeoffs may be initially identified at a more strategic level.

The first level of ‘policies, programs and plans’ is based on the results of the ‘government administration’ sector, aggregated across all levels of government in Australia (Figure 2). This assumes that most promotion of sustainability issues will be borne by the public sector at federal,

[7] Poldy F. (2003). Public understanding and support for sustainable energy. Energy component of online conference ‘In Search of Sustainability”, November 2003. http://www.isosconference.org.au/entry.html Accessed 13-9-2004
[8] Dunlop M., Turner G.M. and Howden S.M (2003). Future Sustainability of the Australian Grains Industry. Contract report for the Grains Council of Australian and the Grains Research and Development Corporation 24-2-2004. Land: Figure 4.2 p73; Water Figure 4.11 p 80. http://www.cse.csiro.au/publications/2004/CSIROGrainsFutures.pdf accessed 13-9-2004.
[9] Lenzen M. (2002). A generalised input-output multiplier calculus for Australia. Economic System Research 13,1,65-92.

state and local levels, and that this activity itself has time imposts and opportunity costs. Thus a quick overview of Figure 2 suggests that there two issues of note with ‘sustainability theorising and planning’. These are that the financial indicators of export propensity and operating surplus are well below the economy wide average. The social indicators are equal to, or are better than average while the environmental indicators are all much better than average. This suggests that ‘theorising and planning’ can be implemented with reasonable social returns and low use of resources. Improvement in exports and profits in a national sense could happen if sustainability services, once proven on the ground, could at least become revenue neutral when citizens and firms paid for them If ‘sustainability services’ develops well, it could become a new source of export income substituting for farm, mine and factory products.

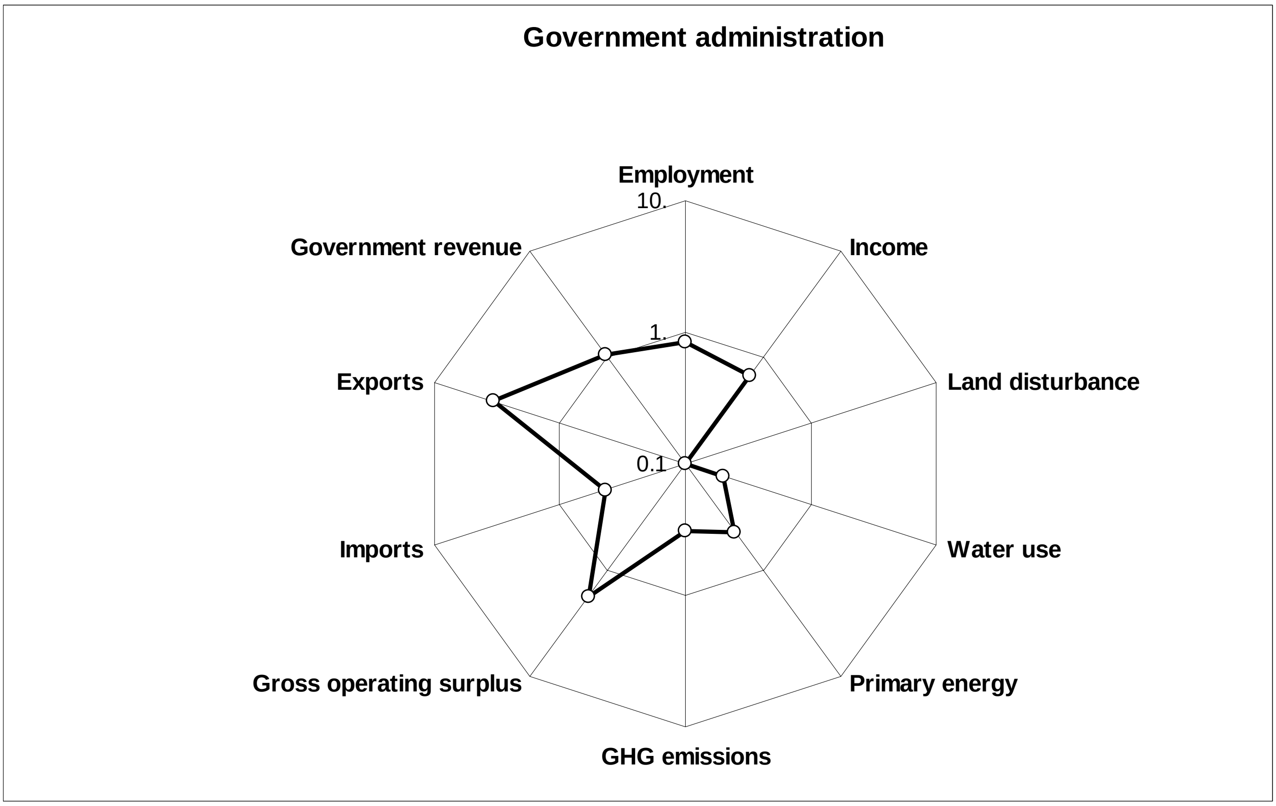

Figure 2. A spider diagram of the strategic overview in triple bottom line terms (financial, social and environmental indicators) of the ‘government administration sector’ of the Australian economy[10]. The equidistant line in the centre is the ‘normalised’ indicator where n=1. Indicators that are placed outside the average to the outer edge of the diagram, may have an issue worthy of further exploration. The indicators that are placed inside the average toward the centre may be considered as good performance or less worthy of further exploration. The financial indicators are gross operating surplus, imports and exports. The social indicators are income, employment and government revenue. The environmental indicators are land disturbance, water use, primary energy and greenhouse gas emissions.

The ‘LNG and LPG’ sector is used as an example of a strategic project, in this case the Gorgon Project quoted in Newman’s paper. It must be noted categorically that Figure 3 represents the sector as a whole, as enumerated in the national financial accounts[11]. It does not include the advanced ‘greenhouse friendly’ designs of the Gorgon Project, nor data reflecting the year 2004 performance of that sector. The major issue for this hypothetical sector appears to be a social one i.e. each dollar of final consumption in this sector has lower than average indicators for government revenue, employment generation and income paid to employees. The sector also may have an issue with higher than average greenhouse emissions which presumably in Gorgon’s case, has been solved by

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[10] Foran, B.D., Lenzen M. and Dey C. (2004). *Balancing Act: A Triple Bottom Line Analysis of the Australian Economy at the 135 Sector Level*. A research contract for the Federal Department of Environment and Heritage (unpublished).
[11] Australian Bureau of Statistics (2001). Australian National Accounts Input-Output Tables 1996-97. Catalogue No. 5209.0

the proposed re-injection of carbon dioxide into the Barrow Island oil field to enhance oil recovery and provide permanent carbon dioxide storage. The lower than average social indicators can be defended on three grounds. Firstly such projects are capital intensive and rely on low labour intensities to maintain their position in a competitive world market. Secondly, petroleum excise is levied on such projects but does not appear overtly in Australia's system of national accounts due to internationally agreed to accounting conventions. Thus the APPEA website[12] records that $3 billion in resource rents and excise was levied on all petroleum sectors over a turnover of $18 billion in the year 2002. Therefore the contribution to government revenue is possibly understated, but questions remain as to the degree of leakage of the resource rents and excise from the region of extraction and their use for a wide range of social and environmental policy issues by governments at all levels. The lower than average income indicators does not tally with the general perception that petroleum workers are well paid for their remote, difficult and dangerous work. These indicators have as their divisor 'one dollar of final demand', this is the total dollar consumed or gained from exports in the sector. Thus petroleum workers are well paid, but not so when their income is divided by the flow of final demand dollars from the sector. Commercial firms would advocate the large and long term commercial risks borne by such deep water petroleum projects. Furthermore they would argue that high returns from viable projects are hardly balanced by the cost of dry holes from many exploration failures. This example shows how a 'triple bottom line' analysis of a 'complex and strategic project' might be guided by an economy wide analysis and from there move on to focus on issues of state government and regional significance. If a similar project were assessed in 'triple bottom line' terms today, the social returns of the project might be subjected to more scrutiny and regional offsets negotiated in return for access to state resources.

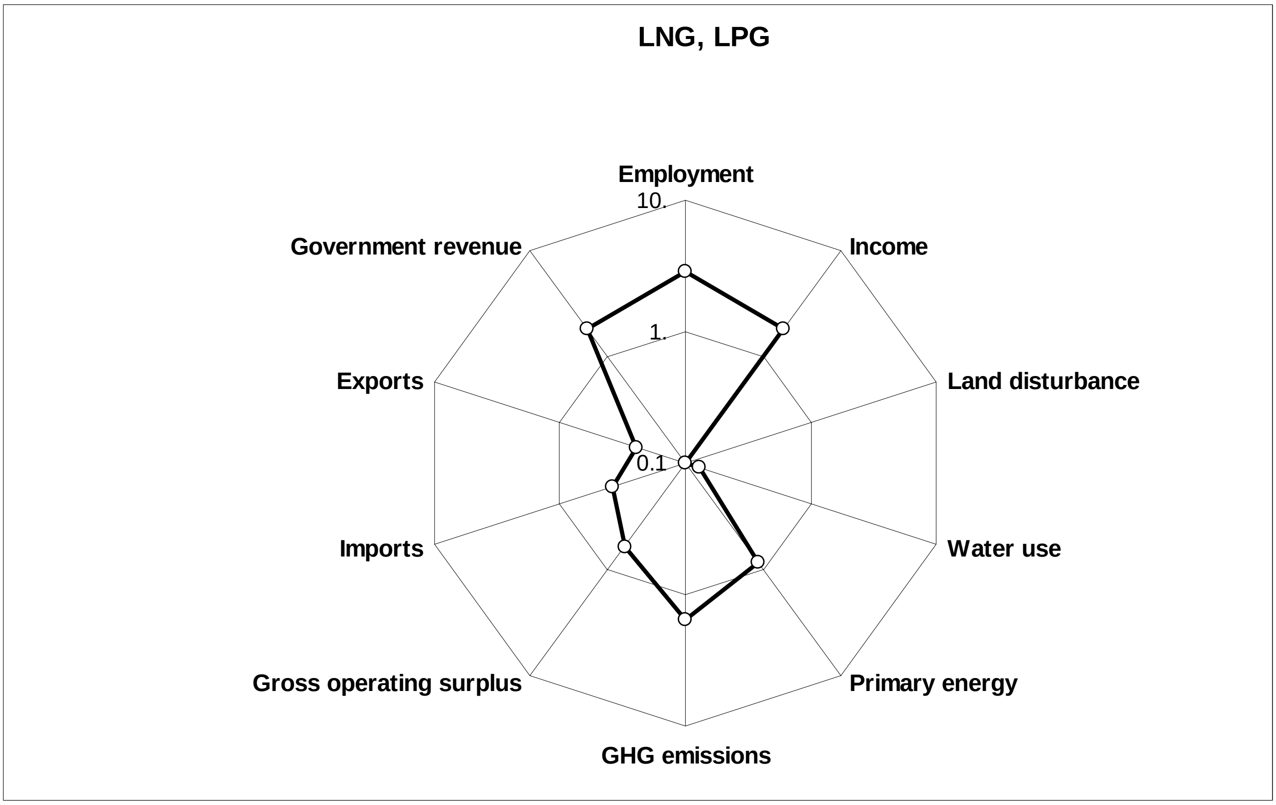

Figure 3. A spider diagram of the strategic overview in triple bottom line terms (financial, social and environmental indicators) of the 'liquefied natural gas' sector of the Australian economy. See caption for Figure 2 to explain the interpretation of the figure.

[12] Australian Petroleum Production and Exploration Association (2004). Indistry Information: Tax and Commercial. Statistics Table 1: Financial Survey Key Results. http://www.appea.com.au/IndustryInformation/TaxAndCommercial/Statistics/fin_Table1.asp accessed 13-9-2004.

The third scale of assessment requirement is for ‘buildings and developments’, the example being given as the new port development in Fremantle (Figure 4). The ‘triple bottom line’ analysis can be commenced by an examination of the ‘non-residential construction’ sector. The national scale overview might conclude that the export indicator is a major outlier, while government revenue and operating surplus are below average. The export indicator is probably not particularly relevant in this sector as a port construction is a local industry, it saves on imports and facilitates the flow of exports rather than being an export in its own right. Balancing the ‘triple bottom line’ is not always possible however, as evidenced by the debate occurring when second hand Bass Straight ferries were purchased overseas when Tasmania has a world leading firm that builds large catamarans. Thus the assessment of the port development can be judged strategically as positive on most counts, opening the way for the local details to become more important.

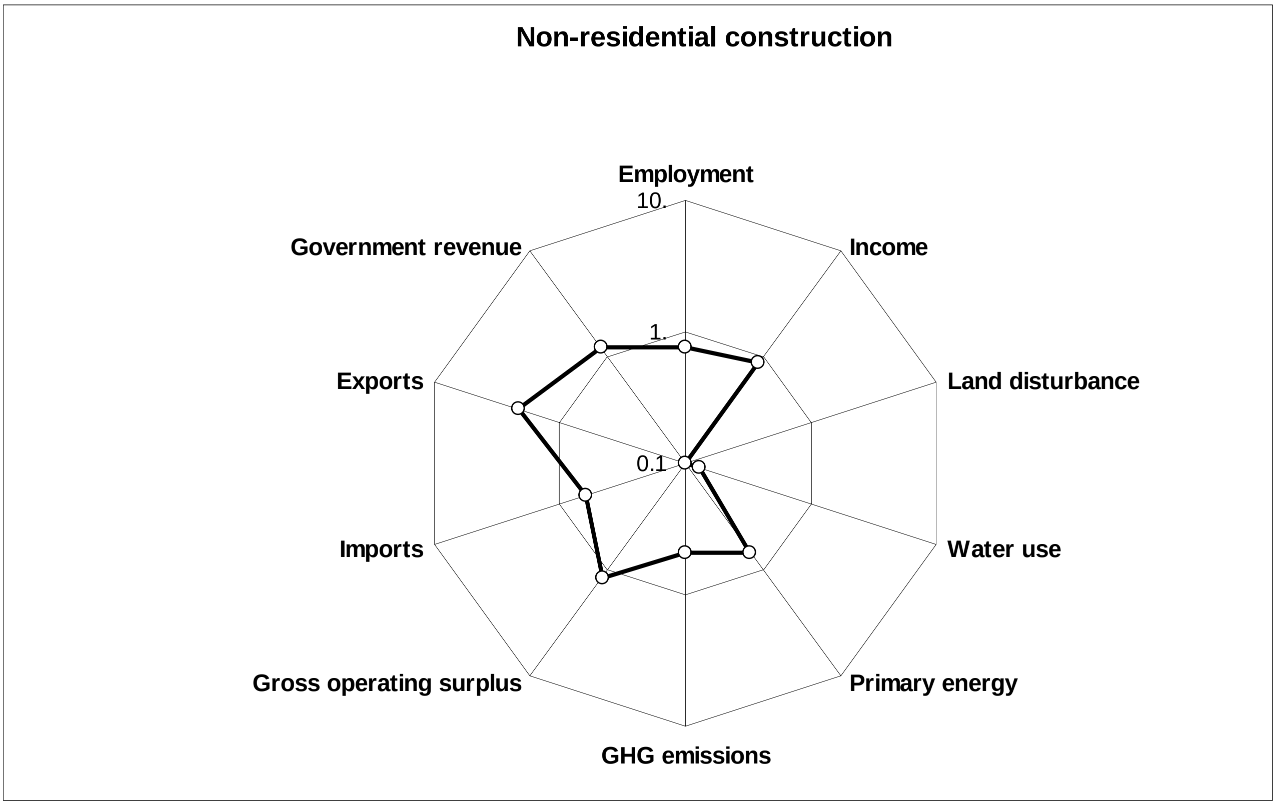

Figure 4. A spider diagram of the strategic overview in triple bottom line terms (financial, social and environmental indicators) of the ‘non-residential construction’ sector of the Australian economy. See caption for Figure 2 to explain the interpretation of the figure.

VISIONS, STORIES AND INDICATORS

The physical economy viewpoint proposes that Newman’s concept of ‘visions, stories and indicators’ can be further elaborated when it iss included in numerate and long term descriptions of the urban system under focus. This allows testing whether such ‘visions and stories’ can actually influence important ‘killer’ indicators of sustainability such as per capita ecological footprints. The experience of whole economy modelling has shown that technological innovation as the sole agent of change can be outrun by a wicked combination of, and interaction between, at least five major ‘primary’ drivers of change. The first is population growth, currently heading towards 25 million nationally by the year 2050. Most state and business leaders prefer higher rates of population growth and so 25 million is probably an under estimate. The second is social change leading to fewer people per household, larger numbers of people living alone thus giving more households as individual nodes of consumption. The third is increasing affluence driven by higher real income levels and higher household debt resulting in the ‘McMansion’ trend in the size of new houses and resources required to build and operate them. The fourth is the ‘within sector’ rebound effect where an increase in engine efficiency in the case of motor cars, can be consumed by additional energy consuming accessories such as entertainment systems and air conditioning. The fifth is the stock inertia effect where innovations take several decades to permeate the operational efficiency of infrastructure, because of the slow rates of turnover or death of that infrastructure because it lives so long. While human brains are highly complex and intuitive in their analytical processing, it is difficult for them to test and debrief the many permutations and combinations required to integrate all of these issues (and more) for the typical design challenges of urban systems.

A simple example relating to car use resulting from these interacting factors is given for a national scale in Figure 5. The fifth of eight vision priorities from the 'Dialogue for the City' process in Perth was a 'reduced car dependence'. While the priorities for Perth were mostly social, this example proposes a policy objective that reduces fuel use to lower air emissions and decrease dependence on uncertain stocks of petroleum fuels. The graph of energy use shows that an average energy efficiency of 10 litres per 100 kilometres will cause fuel use to grow gradually out to 2050, approaching stabilisation as the population number and car ownership level saturates. The technological standard then goes through step changes, first to a hybrid where every new car from the year 2001 is equal to a Toyota Prius or better, and then to the Rocky Mountain Institute Hypercar®[13]. These radical technologies do drive profound outcomes by 2050. However in spite of the step change driven by the 'Prius' option, it still takes until the year 2030 before motor vehicle energy use reduces back to mid-1980 levels. The breakdown by category of use type shows that the proposed Perth strategy of reducing use could have large immediate effects if it were targeted on personal vehicle kilometres, which currently makes up two thirds of total car distance. However Australia's urban structure has evolved over the last two human generations of increasing car ownership to the stage where the personal requirements of childcare, fractured working arrangements, distant shopping centres and diversified entertainment opportunities may simply not function, even if societal spirit was ready to embrace such a 'return to the future'. The physical economy analyst knows that somewhere in the plethora of endless options based on just these two high level graphs, there is a reasonably virtuous zone where both physically feasible and socially acceptable designs possibly come into confluence. Only by merging numerate analysis with 'stories and indicators' will that virtuous zone be identified within an endless maze of contradictions.

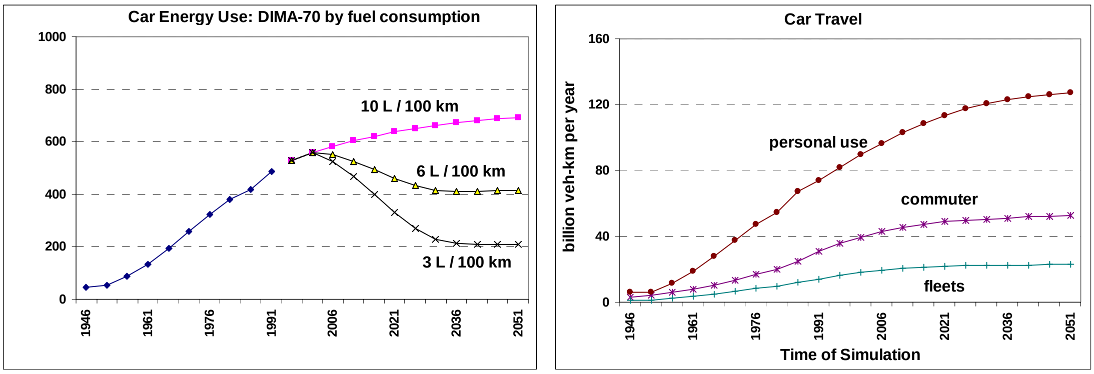

Figure 5. An analysis of car energy use and category of use from the CSIRO *Future Dilemmas*[14] study for the medium population scenario (DIMA-70) which gave 25 million people by 2050. The three future graphs on the left graph (10L, 6L and 3L per 100 km) refer to the average fuel consumption of the national vehicle fleet. The graph on the right divides total car travel in billion vehicle kilometres per year, into the components of personal, commuter and fleet uses.

[13] Lovins, A.B and Cramer, D.R (2004). Hypercars®, hydrogen, and the automotive transition. International Journal of Vehicle Design 35,1-2,50-85. http://www.rmi.org/images/other/Trans/T04-01_HypercarH2AutoTrans.pdf accessed 13-4-2004

[14] Foran B.D. and Poldy F. (2002). *Future Dilemmas: Options to 2050 for Australia's Population, Technology, Resources and Environment.* CSIRO Resource Futures Working Paper Series 02/01, October 2002. 336 pp. http://www.cse.csiro.au/research/program5/publications/02-01.pdf accessed 9-9-2004.

REDUCING THE FOOTPRINT

Most urban sustainability strategies promote reduction of the ecological footprint (the fourth criteria in the WA Sustainability Strategy), but it is usually seen as an aspirational statement rather than using quantitative footprint estimates as hard edged key performance indicators within linked, structured and harmonised strategic plans. The population of Western Australia is expected to grow from 2 million currently to 2.6 million by 2050. This would mean that keeping the total footprint stable (per capita footprint * total population) would require that the per capita footprint be reduced by 25% over the next 50 years. Alternatively taking a 600,000 person increase of state population as a given, a progressive halving in per capita footprint from an estimated 5.5 hectares per capita currently (total footprint of 11 million hectares) to 2.75 hectares per capita, will give a total footprint of 7.15 million hectares. This will allow an important 'killer' indicator to trend in the intended direction. But is such a reduction in footprint size a feasible option?

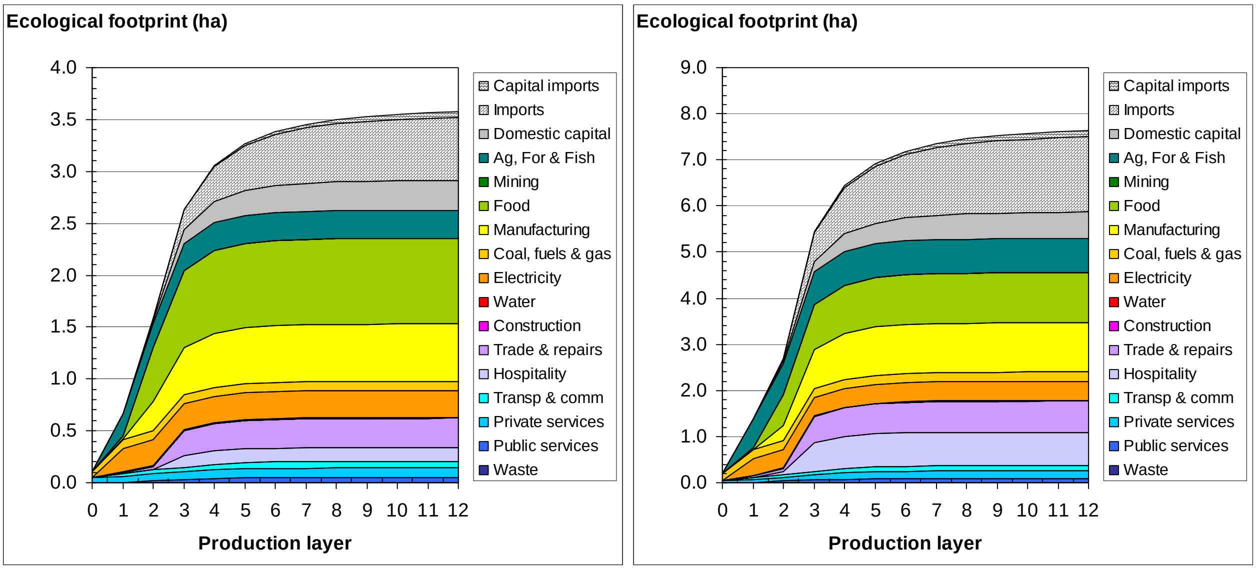

Figure 6. Composition of the per capita ecological footprint described against the layer of the whole-economy production chain for two socioeconomic classes in Canberra. The left graph is for the bottom 20% group of household expenditure. The right graph is for the more affluent lone person households.

The recent study of Canberra's ecological footprint[15] can be used to explore the feasibility of a 50% reduction in its size. This footprint methodology[16] is a development of the original methodology but now uses the national input-output tables and the household expenditure survey as the integrated data base underpinning the analysis. This allows the approach to be used in many locations as well as for diverse products and services (Figure 6). The footprints shown in Figure 6 are for a bottom income group and for a higher income household. Together the two graphs show that footprints in Canberra follow a similar relationship to energy use in Sydney (see Figure 1) with lower spending consumers (the bottom 20%) of income having a per capita footprint of three hectares and higher level consumer with a footprint of nearly seven hectares. The full range of footprint values in the Canberra study is from three to eight hectares per capita. The production layer or production chain approach used, shows that the full influence of the footprint does not become evident until about the seventh layer in the production chain (i.e. suppliers of suppliers of suppliers etc.). While controlling the density of human settlement in urban systems has a range of defensible social and organisational objectives (shown at production layer equals zero), it has only a moderate influence on the eventual size of the footprint at layer 12 of the full production chain.

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[15] Lenzen M. and Dey C. (2004). *Measuring Our Progress-Canberra's Journey to Sustainability: Volume 3 Our Ecological Footprint*. Consultancy Report for the Chief Minister's Department of The Australian Capital Territory. 134pp. http://www.sustainability.act.gov.au/sus_reps/sustain_vol3.pdf accessed 9-9-2004

[16] Lenzen and Murray S (2001). A modified ecological footprint method and its application to Australia. Ecological Economics 37,2,229-255.

One approach to halving per capita footprints in line with sustainability criteria could be by reducing expenditure and consumption levels to the levels experienced by the lower income groups i.e. around 3.5 hectares per capita. This is somewhat at odds with a consumer driven economy and may be infeasible in a both a political and social sense. The obvious question is how might a lone person household, with a seven hectare per capita footprint, use a different suite of technologies and targeted consumption decisions to maintain expenditure, thus keeping the economy growing, at the same time as halving the size of their footprint. Removing meat and animal fibre products from the consumption decisions of a lone person household potentially reduces the footprint by 2.7 hectares, down to 4.3 hectares. The next consumption decision relates to greenhouse emissions for fossil fuel use (electricity 0.35 ha; transport fuel 0.10 ha; natural gas 0.04 ha; total = 0.49ha). Thus running a household completely on renewable electricity, cycling everywhere instead of using a car, and heating the house with plantation wood, could reduce the lone person's footprint down to 3.8 hectares. The next set of consumption decisions are much harder won as each substantive decision yields a smaller incremental return. Thus two major consumption decisions on animal products (no beef, lamb or wool) and no fossil energy (electricity, petrol, gas) have nearly halved the per capita footprint. Changing the building footprint (high density housing versus the urban quarter acre block) might give a direct saving of 0.04 hectares. However these high density decisions could give knock-on footprint reductions if this housing infrastructure was located close to the city centre and stimulated walking and cycling, instead of car and bus usage.

Re-examining Figure 6 reveals a large block of footprint activity, as yet unscathed by the footprint reduction process i.e. imports. These account for nearly two hectares of the lone person household's footprint, and 0.7 hectares for the bottom expenditure household. It is doubtful whether Australia's sophisticated and 'brand name' orientated consumers could do without imported motor cars, computers, entertainment products, running shoes and mobile phones. Nevertheless this component of the footprint makes a similar point to a recent material flow (a similar analysis to the footprint but expressing environmental loading in tonnes per capita rather than hectares per capita) analysis of the UK economy[17]. This report noted that a strongly performing economy was improving at home environmentally, but placing increasing material burdens on many of its trading partners. Some of the hard analysis backing up the 'killer indicators' espoused by Peter Newman highlight some issues that might be unpalatable for many of today's urban consumers. However given this entrée into urban system designs for sustainability, the task for the physical economy analyst should be to promote some of the more difficult decisions to urban communities now. Then the process of 'story telling' and the 'reinvigoration of democracy' promoted by Newman can force the rate of innovation and change and hopefully work their magic over the next 25 years.

SIX PRINCIPLES OF PHYSICAL SUSTAINABILITY

From the more limited view of physical sustainability noted in the opening perspective section, there are six important principles that could guide a whole economy approach. These are distilled from many simulation runs of our whole economy models and reams of physical economy reading. They have not received the societal focus of the Western Australian 'Foundation Principles' nor is there one 'sustainable Australia' design published in the peer reviewed scientific literature. Instead the six principles are active responses to national sustainability issues and characterised as being 'primary' rather than proximate drivers of environmental change. Each principle is characterised by five short statements, the first of which describes its function and the rest are technology or institutional subsets which are less complete.

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[17] Department for Environment, Food and Rural Affairs (2002). Resource Use and Efficiency in the UK Economy. A Report by the Wuppertal Institute for the Department of Environment Food and Rural Affairs. June 2002, 22pp.http://www.defra.gov.uk/environment/statistics/waste/research/download/mfaressum.pdf accessed 10-9-04

1. Stabilise human population number and age structure

- Population number multiplies all per capita consumption activities so a larger population will produce a larger environmental loading and resource requirement than a smaller one.
- Population growth contributes nearly half of overall growth in GDP or its state and regional equivalents, primarily through growth in direct consumption activities but also through the stimulation of suburban construction and the chain of activities that underlie it.
- A more or less stable age structure, particularly if it is well mixed within suburbs, stops booming and busting in urban areas, their infrastructure and social services. Urban authorities can then focus on quality rather than quantity.
- Australia's population can grow to a more or less stable population number of around 25 million by the year 2050 without radical change to immigration levels, refugee intakes and multicultural policies.
- Managing the age structure of human population is somewhat more difficult but urban areas can be made equitable, friendly, culturally rich and safe for all age classes with many of the planning criteria listed in Newman's Table 3, "Dialogue for the City" process.

2. Constrain and reduce the grand element flows: carbon, nitrogen, phosphorus, sulphur and water (not an element)

- The main challenge to the health and function of the global biosphere comes from the continually growing use of fossil carbon (greenhouse gas emissions), industrial nitrogen (fertilisers), phosphorus (fertilisers), sulphur (sulphur dioxide causing acid rain and acidification) and water (intensive food production)
- The global outcome is that the buffering ability of natural systems is now overtaxed in many areas and there is widespread toxification of food production systems and natural ecosystems with looming challenges in productivity in 50-100 years time
- Local examples of this are the growing acidification of both croplands and pastures, algal blooms in rivers and estuaries and possible climate shifts during the next century with changes in rainfall amount and season.
- International examples are the large dead zone in the Gulf of Mexico due to intensive land use and nutrient export from the Mississippi River Basin, the death of the Aral Sea and its fisheries in Russia, and widespread nitrification of groundwater aquifers throughout Europe.
- These are globally systemic issues according to Vaclav Smil[18] who contends that had it not been for the invention of the Haber-Bosch process to fix atmospheric nitrogen industrially, the world could feed no more than three billion people on agricultural systems enriched by legume crops and animal wastes, rather than nitrogen fertiliser out of bag.

3. Base society and economy on cycling (flows) rather than reliance on accessing virgin materials (stocks)[19]

- To change the globally systemic problems presented in Principle 2, economy and society must work more within the cadences and flows of natural systems, rather than work on dominating and homogenising natural systems.
- This requires an economy based on intellect and information integration rather than brute force. However it does not signal a reversion to the human chain gang to replace the backhoe and the bulldozer.
- Energy systems would retrofit the traditional base load electricity plants taking them to the leading edge of thermodynamic efficiency. However the requirements for growth would

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[18] Smil V. (2001). *Enriching the Earth*: *Fritz Haber, Carl Bosch and the Transformation of World Food Production.* The MIT Press, Cambridge Massachusetts and London England. 338pp

[19] Folke Gunther (2003). Sustainability through local self-sufficiency. in *Before The Wells Run Dry: Ireland's Transition to Renewable Energy* Edited by Richard Douthwaite. Green Books Devon UK. 333pp.

come through energy saving (overall reduction and more efficient end uses) and through new energy from wind, photovoltaic, solar thermal and biomass fuels which are all flows (wind, sun, plant growth). Fossil carbon would be taxed.
- Agricultural systems would become more biological and less chemical, and rely on the refurbishment of soil structure and soil biodiversity to substantially make available and replenish the nutrients that currently come from a bag. Lower yields would be balanced by lower input costs, and more 'naturally' produced foods may eventually attract market premiums from environmentally attuned consumers.
- Stewardship and 'industrial ecology' programs for many industrial materials and feedstocks could substantially replace the need to mine and refine virgin metals. Material flows in consumer society may be highly regulated and perhaps taxed heavily.

4. Shorten the supply chain

- Shortening the supply chain and bringing many urban support services back into each suburb reconnects urban people with nature, waste processing, food production and the supply energy and water. Currently many materials and services are transported over long distances challenging Principle 2 and giving perverse outcomes often based only on market price advantages, and ignoring indirect environmental degradation, inequitable labour practices and long distance transport of nutrients and water.
- Applying this globally would inevitably reduce the volume of internationally traded goods and commodities and challenge Australia's international trading balances if it were implemented today. However national competitive advantage in particular commodities, skills, goods and services would endure and be constantly changing. Financial returns could even increase if fair pricing of the ecosystems services and labour skills embodied in the product were agreed to by international protocols.
- Local food production would be encouraged in backyards and within city boundaries and 'out of season' imported luxuries such as cherries and grapes may become less available. Apart from the reconnection of urban citizens to land and nature, the key production chain issue is to allow recycling of organic waste, human faeces and urine directly back to nearby commercial farms particularly to conserve and recycle elemental phosphorus. Commercial farming would stay a mainstream activity for domestic requirements and high value exports.
- New suburbs may be designed to supply half of their electricity and water from within their own boundaries. This would engender local responsibility and management of consumption levels. The water and electricity grid could flow both ways and buffer system breakdowns at a local level.
- In addition to the material flow rationales for shortening the supply chain, the substantial returns are social ones. Job creation is partially localised to support the task of living sustainably rather than simply consuming. Monetary flows can be recycled within the community and 'local money' or 'time dollar' systems allow skills and time to be interchanged, without financial transactions. Most people would still be active in the traditional economy but would live in more resilient and self supporting communities.

5. Engineer society for durability[20] and resilience[21]

- Durable engineering in a society means that societies' infrastructure and artefacts last a long time and are able to be repaired easily and upgraded and re-engineered to achieve higher levels of performance and lower environmental impacts

[20] Slesser M. and King J. (2002). *Not By Money Alone: Economics As Nature Intended*. Jon Carpenter Publishing, Oxfordshire, UK.160pp.

[21] Holling, C. S. (2004). From complex regions to complex worlds. Ecology and Society **9**(1): 11. [online] URL: http://www.ecologyandsociety.org/vol9/iss1/art11

- A resilient society is one where its governance institutions, its financial systems and the basic resources that drive food, energy and utility systems are reasonably harmonised and not unbalanced by high levels of debt, resource constraints, pollution generation and over-reliance on international trade for key systems of society support.
- A society characterised by durable engineering and resilience can be seen as being at odds with many contemporary societies but there are many durable and resilient aspects to everyday life. Bridges and aeroplanes are built to be durable while many fashion items and electronic goods have a built-in obsolescence. Parliamentary democracy and national constitutions are extremely resilient, but many community care, health, and education systems are showing signs of teetering on the edge of becoming less resilient.
- New engineering standards particularly in the European Union are guiding the development of many consumer items so that they have less complex composition, are easily disassembled and re-engineered, and can easily be recycled. This is the new ‘cradle to cradle’ lifecycle philosophy, compared to the previous ‘cradle to grave’ philosophy.
- Thee is a risk that blind adherence to the ideals of durability and resilience could lock-in an antiquated economy without the skills and drive to respond to emerging challenge and new opportunities. The ideals of durability and resilience have to focus on containing and reducing material flows for the total economy, and the physical systems that provide food, energy and water.

6. Ensure that “taxes tell the truth” by aggressive taxation of carbon, water and land disturbance

- This sixth principle proposes that national taxation systems respond to the overuse and inappropriate use of fossil fuels, water resources and land by implementing over two decades, the progressive replacement of employment and income taxes with physical taxes on the greenhouse, water and land content of all goods and services.
- In most nations the right to a place in the paid workforce is seen as an unqualified ‘good’. Yet current taxation systems penalise employees through income taxes and employers through payroll taxes. Most let resource use go untaxed, recouping in most cases just the marginal costs of utility management. This approach would allow worker’s wages to go untaxed until a consumption decision is made.
- The truth-in-taxes approach uses the economic dictum of ‘internalising the full cost of production within the market price of a good or service’ with well developed free market mechanisms that allow innovative and sophisticated responses from both producers and consumers. For example, if life cycle analyses reveal that intensive meat production systems have high contents of greenhouse gas, water and land disturbance embodied in their full production chain, consumers can choose to pay a much higher price to maintain their meat consumption habits while producers in parallel may choose to innovate and develop less materially intensive production systems.
- Full production chain analyses[22] are now available for 135 sectors of the Australian economy which will reveal the resource content of most goods and services. This will allow system wide examination of where production chains require improvement and also will allow numerate product labelling.
- A logical outcome of a physical taxation system is that the costs of food and transport in particular could increase several fold. This will put lower income consumers, some commodities and many industries under significant pressure in financial viability and even survival terms. A twenty year transition and the use of established revenue collection mechanisms such as an augmented ‘goods and services tax’ would allow adequate institutional opportunities for trade offs, compensation, restructuring and retraining.

[22] Foran, B.D., Lenzen M. and Dey C. (2004). *Balancing Act: A Triple Bottom Line Analysis of the Australian Economy at the 135 Sector Level*. A research contract for the Federal Department of Environment and Heritage (unpublished).

CONCLUSIONS

Stories and statistics

Few could argue against the premise that reconciling the approaches of 'stories' and 'statistics' provides a practical way forward for the task of resolving the tension between our social and economic aspirations, and the physical reality that humankind's progress is literally consuming the earth. Merely monitoring this tension with good intentions and 'killer indicators', is unlikely to catalyse the considerable changes required in the volume and composition of our personal consumption that forms the root cause of the sustainability challenge. One of Winston Churchill's dictums was that, "*People and nations behave wisely-once they have exhausted all other alternatives*"[23]. Will it in the end require an unimaginable crisis to spur that change, or can we design our way through it before then? The next two decades will tell!

Sighted or blind?

Implementing the stories (past history and future scenarios) and statistics (drivers and indicators) in numerate analytical frameworks that can simulate urban designs over the next 100 years provides a practical way of resolving human aspirations and physical realities. Already there are incomplete examples of how to go about this at a national scale[24]. Plans are being developed to implement similar frameworks for the city of Melbourne and the state of Western Australia. So science has a partial way forward, but is still a long way from having well rounded solutions.

Inertia and rebound

Unless citizens, policy makers and technocrats understand and learn to manage inertia and rebound, then sustainability principles are probably doomed to failure. The concept of *inertia* comes from physics. It is used for urban systems to describe the rate at which stocks of cars, buildings and industrial machinery become obsolete and are replaced, so allowing innovation and the infusion of new technology. *Rebound* is an economic concept with important physical dimensions that describes the way increasing the system efficiency can release resources to enable further expansion. It is probably the main driver of economic growth over the last two centuries and has what is called a 'wicked' feedback. In a deregulated economy in the long run, increasing the efficiency of energy use for example will probably dictate that more energy is used in total. A rebounding economy allows increasing efficiency to catalyse growth, often to the detriment of important environmental indicators such as greenhouse emissions.

Bridging the scales of the 'triple bottom line'

The strategic approach to 'triple bottom line' analysis described earlier allows a bridge between the scales of policies and programs (the WA State Sustainability Strategy), strategic projects (the Gorgon gasfield) and local development plans (the new Fremantle port development). Central to this approach is that both direct effects and the indirect effects hidden in the entire production chain can be made transparent. This is somewhat analogous to the concept of the ecological footprint, but 'writ larger' over a set of politically important indicators. These TBL intensities are referenced against 'one dollar of final demand' and thus financial budgets can be simply and routinely assessed for their wider sustainability implications.

Continuing tensions between the analysts and the clients

Using the integrative and whole economy tools we see as central to the long term sustainability debate, creates significant and almost irreconcilable tensions between the analysts and many of their bureaucratic and political clients. Newman's paper notes that "*planning for sustainability process cannot be divorced from politics*" and that "*institutional processes are not proceeding quickly*

[23] In: Boyd, D.R. (2004). Sustainability within a Generation: A New Vision for Canada. The David Suzuki Foundation. http://www.davidsuzuki.org/files/WOL/DSF-GG-En-Final.pdf Accessed 10-9-2004
[24] The 'Australian Stocks and Flows framework' used in the 2002 *Future Dilemmas* study conducted by CSIRO

enough to cope with the integrative processes required within government". The physical economy view would not disagree! It also contends that social and environmental goals are often diluted to accommodate economic goals. This in turn contravenes the 'Foundation Principles' shown in Newman's Table 1 where as an example, 'Long Term Economic Health' has a primacy of place. To resolve these tensions adequately, a new form of economics may be required although some practitioners claim the current anomalies result from poor economic practice, rather than poor economic theory.

Focusing on the primary drivers rather than the proximate ones

Intellectual leadership is required to highlight the 'primary' drivers of poor social and environmental outcomes in urban systems. This enables these main drivers to become the focus of innovation and change, rather than the proximate (or secondary) drivers of change. In the greenhouse gas emissions example given earlier, four primary drivers or 'accelerators' of emissions growth were identified. These were economic growth, population growth, export volume and industrial structure. By societal definition, many of these drivers cannot be altered in the quest for sustainability although some of them are the drivers of un-sustainability. Instead the 'end of pipe' proximate drivers become the policy focus, such as better urban structure, improved transport modes, resource pricing and sustainability assessment. Implementing the 'stories and statistics' in complex but well designed calculators will possibly allow the complex nature of these tensions to become separated out and therefore more transparent.

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