Doing more with less through integrated and symbiotic solutions: Use of product-service systems for resource efficient regional development

David Ness[1], Ke Xing[2], Brian Webby[3]

[1] Barbara Hardy Institute, University of South Australia, Adelaide, South Australia 5000, Australia
[2] School of Advanced Manufacturing and Mechanical Engineering, University of South Australia, Mawson Lakes, South Australia 5095
[3] Barbara Hardy Institute and Centre for Regional Engagement, University of South Australia, Whyalla, South Australia 5600

Abstract

Research on Product-Service Systems (PSS) has largely focused on delivering more efficient and effective services via manufactured products within the business world. There has been relatively little research on the application of PSS principles to planning of services and facilities for sustainable development within wider environmental, social, and economic contexts.

This paper shows how PSS principles and methodologies may be used for development of a region so that ‘achieving more with less’ can be realised through integrated and symbiotic solutions. By applying a conceptual model to a case study industrial region in South Australia, the paper indicates how this approach may not only improve resource efficiency, but also deliver multiple environmental and social-economic co-benefits, with improved community engagement. It tests the proposition that more effective and efficient services may be delivered with less physical resources, less waste, less emissions and less cost, by uncovering interconnections and creative synergies between various services and between supporting infrastructures, facilities and products. These may be regarded as a series of product-service systems involving products, services, networks of actors and supporting infrastructures that satisfy customer needs in a competitive and efficient manner. Within the context of systems theory and soft systems methodology, the paper extends earlier concepts of PSS as a framework for ‘value co-production and creation’, and shows how this may be applied to regional planning.

Keywords: Product-service systems, resource efficiency, symbiosis, integration, regional development

1. Introduction

This paper aims to extend the concepts and application of product-service systems (PSS) and industrial ecology beyond the business and manufacturing sector to the planning of a region.

It seeks to link PSS concepts and approaches with Soft Systems Methodology (SSM), which is seen as an especially valuable means of drawing together the diverse views and values of multiple stakeholders to achieve sustainable system and community transformation. A functional framework is proposed, integrated with PSS design tools, to direct the formation of a 'solution-oriented partnership' (SOP) to explore and capture synergism among PSS elements, and to drive the co-production of product-service solutions to achieve 'creative holism' (Jackson, 2006).

The theory of PSS is first outlined in Section 2, followed by a review of literature to determine the extent to which this has been applied to industrial ecology and wider regional sustainability, and to identify the gaps. PSS is then positioned within systems theory, especially soft systems methodology (SSM). A new model for synergistic regional transformation is put forward in Section 3, using PSS principles in conjunction with soft systems methodology. In Section 4, the model is then applied to a case study industrial region, with the purpose of illustrating how this may open up opportunities for creative synergies that support the achievement of regional objectives in a more resource efficient manner, doing more with less. The theme of renewable energy is used to explore a PSS mode in some depth. Finally, in Sections 5 and 6, the implications of the findings for synergistic or symbiotic sustainability are discussed and areas for further research are identified.

2. Theory

2.1 Industrial and Regional Symbiosis

Industrial ecology seeks to apply the principles of natural eco-systems to industry, whereby the 'waste' from one enterprise provides the raw materials for another, forming closed loop systems (see Tilley, 2003). Symbiosis is a biological term which the Collins Dictionary (1995) defines as 'a close association of two different animal or plant species or groups living together to their mutual benefit'. As Chertow (2000) explained, industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage, involving physical exchange of materials, energy, water and/or by-products. The key to industrial symbiosis is collaboration and the synergistic possibilities offered by geographic proximity. This was well demonstrated in the innovative industrial district at Kalundborg, Denmark, during the 1990s (Ehrenfield and Gertler, 1997). More recently, Baas (2011) and others have sought to apply these principles to broader symbiotic planning within the region of Östergötland, Sweden, embracing the twin cities of Linköping and Norrköping and 80 industrial organisations.

Mirata and Tareq (2005), cited by Baas (2011), described the networked approach as '…a collection of long-term, symbiotic relationships between and among regional activities involving physical exchanges or materials and energy carriers as well as the exchange of knowledge, human or technical resources, concurrently providing environmental and competitive benefits…'. In line with this thinking, Harvey and Cheers (2011) emphasised that 'communication and exchange between diverse sectors can create links between the development of ideas and initiatives originating from stakeholders, in addition to physical exchanges'.

2.2 Resource Efficiency

As encapsulated by Schmidt-Bleek (2000) and others, the concept of resource efficiency (RE) involves delivering more services (S) or outputs, with less material input (MI). In simple terms, resource efficiency is the amount of resource used per unit of input - similar to the concept of material input per unit of service (MIPS). The less the material input per unit of output or service, the greater is the resource efficiency, and vice versa. Conversely, resource productivity is the economic output or value added per unit of resource use; it is often designated as the reciprocal of MIPs i.e. S/MI (Wallbaum and Buerkin, 2003, Ritthoff et al., 2002).

Von Weizsäcker et al. (1998) argued that we need to achieve a Factor 4 improvement in resource productivity, that is, a doubling of prosperity in terms of service outputs, whilst halving resource consumption or material inputs. This has since been extended to notions of Factor 5, Factor 10 and Factor X (Reijnders, 1998). Of special note, based on earlier work of the Rocky Mountain Institute, von Weizsäcker et al. (2009) have advocated a 'whole system approach to resource productivity', through which the interconnections between systems are actively considered, and solutions are sought that address multiple problems at the same time. Such an approach can create cumulative and synergistic improvements in resource efficiency and productivity. UNESCAP (2011) has illustrated the application of these principles at an urban and community-wide level, involving 'orchestration of sectors' and 'harnessing existing assets' to create more value for citizens whilst reducing the use of resources and the production of waste and pollution. Ness (2011) has used 'The Tower of Jin Shan' in Zhenjiang, China, as a metaphor for a wider 'View from the Top' to take a holistic view of all dimensions of sustainable systems for a green economy, with various levels of achievement (see also Baas, 2011, 112).

2.3 Product-service systems

The notion of improving resource productivity by providing more output (services) with less input (resources) fits well with the concept of a product-service system (PSS).

In PSS, physical, or tangible, *product* entities are responsible for carrying out the functions of PSS, while nonphysical, or intangible, *service* entities are to ensure the smooth delivery of the functions (Maussang et al., 2009). PSS mechanisms have been seen as a way of delivering improved services with less products and resource use. As Ayers (1999) described in his seminal paper, 'since products are essentially carriers of service, the trick is to find ways of delivering the service without wasting the material carrier…the messengers need to be used many times, not merely once'. In other words, we need to find ways of gaining the most value and services from limited physical resources and products.

As Roos (2012) pointed out, manufacturing is a major employer especially if this can be combined with related services, such as in product-service offerings: the business of making things – including services and solutions provided by manufacturing firms - probably represents, as a share of GDP, more than 30 per cent of an advanced (or innovation) economy'. The concept of PSS involves a shift from the sale of manufactured products to providing these to customers as part of a service, akin to rental or leasing. This enables the producer/service provider to exercise stewardship over a product or resource, enabling it to be taken back and reused many times to deliver services to the customer, thereby reducing energy, emissions and waste, all in keeping with Ayers' philosophy (see Ness et al., 2005). It also affords an opportunity for improved services and new profit centres via the continuing relationship between service provider and customer, with mutual benefits. Furthermore, PSS can offer a 'triple win' (people, planet, profit) scenario that combines sustainable concepts with powerful presence in the market place, where 'a company's commercial value creation goes beyond the spreading of material goods' (van Halen et al., 2005).

PSS mechanisms may not only involve product-oriented services (e.g. product take-back, rental and management) but also knowledge-oriented services (e.g. consulting, training), labour-oriented services (e.g. cleaning services) and result-oriented services (e.g. energy saving contracts) that focus on providing customers with a specific result rather than a specific product. Mont (2001) has described how PSS approaches may apply to utilities such as energy or water, where the profit centre is not in the amount of electricity or water sold, but in the provision of a constant input of products and in the reduction of this flow - so the customer pays for efficiency, as in the case of Energy Services Companies (ESCOs). Mont (2001, 63) also suggested the profit centre could be shifted towards the function provided e.g. 'keeping temperature in the house at 20 degrees during the day', giving the provider an incentive to widen the scope of the service e.g. to check whether the house is insulated. Yet another application of PSS is to the provision of chemical services, where the chemical management services model CMS model transforms chemical suppliers into service providers, and creates mutual incentives to reduce costs, chemical use, and waste generation while improving overall resource efficiency (Mont, 2001, p.64).

Such PSS approaches have been mainly applied to the business and consumer sectors, where individual products, services, networks of actors and supporting infrastructure all strive to satisfy customer needs in a more competitive manner than traditional business models (Lay et al., 2009; Mont, 2004). However, some authors have sought to extend PSS thinking beyond individual products to wider systems, suggesting this may simultaneously increase customer satisfaction, profits and eco-efficiency (Manzini and Vezzoli, 2003). A PSS business model may be accompanied by new types of partnerships among stakeholders with connected economic interests and a shared vision of desirable outcomes for 'system resource optimisation' (Morelli, 2006).

This paper seeks to extend this thinking to a region, whereby multiple services are provided from limited products and local resources by means of symbiotic approaches and system optimisation. This can result through stakeholder partnerships, sharing facilities and infrastructure, and keeping resources within closed loop systems.

2.4 Use of systems theory and PSS to drive synergistic relationships

Synergy is regarded as a paradigm of 'science of relationships' that focuses on interactions among entities (parts or wholes) (Corning, 1998). The benefits of synergetic approaches are already well understood; for example, in the field of industrial ecology, enterprises are interconnected and processes are symbiotic and mutually reinforcing (Baas, 2011).

Beginning with simple bundling of products and services, the basis for PSS development is the belief that there is a form of symbiotic relationship between products and services in delivering the desired results for customers, which neither is capable of achieving on its own. In particular, as noted by Partidário et al. (2007) and Pawar et al. (2009), co-development and co-delivery of PSS solutions has notable power for service system innovation; harnessing the complementary competencies, resources and capability of different organisations makes it possible to produce services beyond the scope and capability of individual organisations. Cooperative partnerships involving heterogeneous organisations and the synergistic functional effects thus produced are essential for value creation and augmenting the benefits of PSS, especially in the context of community transformation for 'strong sustainability'. Such understanding is not totally new to PSS research and practice. Jégou and Joore (2004) and colleagues within the 'Suspronet network', including Manzini et al. (2004) and Krucken and Meroni (2006), discussed the concept of 'solution-oriented partnership' (SOP) and methods to develop PSS solutions based on SOP. Core to SOP is a system approach for formation and collaboration of networks of partners with a common vision and the capacity to develop context-focused, sustainable solutions.

3. A new eco-system model of symbiosis

A new eco-system model is proposed for service innovation and systems solution development, utilising the synergistic relationships among PSS elements, including soft systems methodology (SSM) principles (see Checkland, 2001). The process 'flows' and interconnections among the PSS elements are illustrated by the 'synergism clouds' (Figure 1).

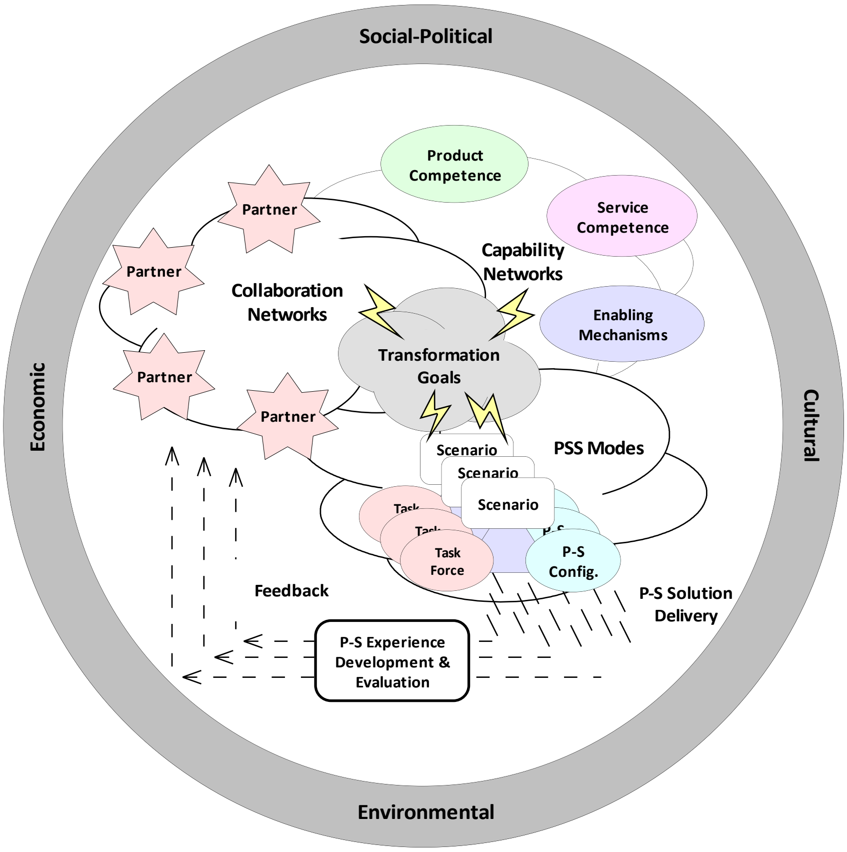

Figure 1. Eco-system Model of Symbiosis for PSS Development

The key elements and processes of the model broadly align with the SSM stages described by Checkland (2001) and the UN strategic planning process for eco-efficient and socially inclusive infrastructure, namely 'Where are we now?'; 'Where do we want to get to?'; 'How do we get there?'; and 'Are we getting there?' (UNESCAP, 2011, 60). The architecture of the model consists of five major components:

- *Context and Boundaries* are signified by the ring-shaped outer layer in the figure and include the environmental, economic, cultural, and social-political perspectives for investigating the issues and opportunities for contextual solutions development. As in SSM, the viewpoint and boundaries may be adjusted *i.e.*, 'zooming out' for synthesis or 'zooming in' for closer analysis.
- *Collaboration Networks* are networks of SOPs that involve groups of heterogeneous stakeholders (such as people in the community, corporative entities, government agencies, financial institutions, NGOs, etc.) that have similar interests for 'value co-production' (Ramirez, 1999).

- *Capability Networks* actually represent the competencies of the participating entities in terms of the goods and hardware that they can provide, the kinds of services that they can offer, and the resources and infrastructures that are available for solution development.
- *Transformation Goals* are in the centre of the model and are defined to reflect shared worldviews and to state the desired purposes and outcomes of transformation agreed upon by the stakeholders.
- *PSS Modes* represent a cluster of possible solutions to address the defined 'problem situation' and to achieve the desired transformation. A PSS mode consists of a scenario (indicating a theme for change), a task force (i.e., a group of participants that collaborate under the particular theme), and the product-service configurations (representing the specific technical and service solutions related to the theme).

Based on a holistic view, different PSS modes can be interconnected through synergies among their scenarios, task forces and PSS configurations, with overlaps in the resources and actors involved, as illustrated in Figure 2. Such interconnections are often important for the efficiency of resources and infrastructures and essential for the viability of the solutions.

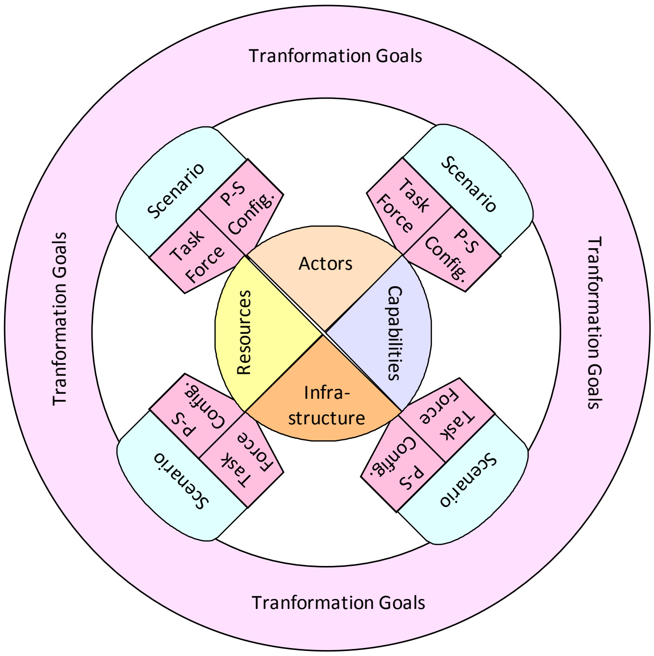

Figure 2. A Holistic View of Connections between PSS Modes

4. The Case Study: Upper Spencer Gulf, South Australia

4.1 The context and boundaries (understanding the problem)

The Upper Spencer Gulf (USG) contains the three regional cities of Whyalla, Port Augusta and Port Pirie, spaced 80-90 km apart around the waterway which gives the region its name. The cities are also known as 'The Iron Triangle' due to their geographic relationship and their mutual focus on heavy industry. Whyalla is characterised by its iron ore exports and steelworks, Port Pirie by its lead and zinc smelter, and Port Augusta by its coal-fired power station. While the cities hug the coast, their hinterland contains extensive rural and semi-arid areas, and sites of intense resource extraction such as the vast Olympic Dam mine (copper, uranium, gold and silver) presently under appraisal for expansion (BHP Billiton, 2011).

The boundary of the study is thus drawn not only around the three regional cities, but also extends to their resource rich hinterland, as illustrated in Figure 3.

Figure 3. Map of Upper Spencer Gulf Region and Its Hinterland (adapted from http://wwp.greenwichmeantime.com/time-zone/australia/south-australia/ and Government of SA, 2005).

The USG is a gateway and service provider to the resource rich northern areas of South Australia. A new deep water port on the Point Lowly peninsular and other facilities are currently under consideration. Such industrial developments pose a threat to the natural environment, including marine life (e.g. the giant Australian cuttlefish) and areas of natural beauty and conservation value, and require resources such as materials, energy and water. Fresh water is a limiting resource for the region. Currently, water is piped 379 km from Morgan on the River Murray and is able to meet a demand of 66,000 megalitres a year. Water scarcity may be exacerbated by increased demands from industry, climate change, and competition for water rights available through the River Murray system that serves several Australian states.

The region has traditionally been viewed as dirty; Whyalla has a patina of red dust from iron ore processing, blood-lead levels pose health concerns in Port Pirie, while emissions from burning coal for power generation have long been an environmental and health concern in Port Augusta (Gage, 2012). The introduction of a tax on carbon emissions in Australia further compounds the complexity of the challenges facing the region, impacting severely on the smelters and the power station. For example, the tax will cost a local zinc and lead smelter in Port Pirie up to A$4.25 million yearly from 2012, coupled with pressures to rebuild the smelter at a cost of A$350 million so that targets for reduction in lead emissions may be attained (Littley, 2012). The industries are seeking compensation and contemplating down-sizing or even closure of their operations, impacting on employment and the viability of the region (see Ramsay, 2011; Australian Government, 2010).

It is noteworthy that each city is attached to a different Regional Development Australia (RDA) region: Port Augusta under the ‘Far North’, Whyalla under ‘Whyalla and Eyre Peninsula’, and Port Pirie under ‘Yorke and Mid North’. Each RDA committee prepares plans to develop ‘local solutions to local issues’. However, an USG ‘Common Purpose Group’ (CPG) was established in 1999 in an attempt to reverse the deteriorating economy of the USG by fostering cooperation and collaboration between the local governments, industries and businesses of the three cities within the region. As Harvey and Cheers (2011) described, previous attempts to strengthen the regional economy through government programs had failed to reverse the decline, due in part to the region's long history of intercity rivalry and insularity. They observed: 'the formation of the CPG represented an initially tentative move from separate and, in some ways, parochial and competitive attempts to tackle the economic, demographic and social decline of the three cities to focus on collaboration as a vehicle for repositioning and reinvigorating its competitive advantages over a ten year period'. The current resource boom provides an opportunity for the USG to further develop and market its expertise in industrial fabrication, construction and maintenance, its facilities for processing, transport and export of minerals, and its capacity to provide education, recreation and dormitory services.

4.2 Transformation goals ('where do we want to get to?')

Based on SSM, understanding and learning about a problem can lead to deliberate actions to bring about improvements. The 'transformation goal statement' should encapsulate some systems of purposeful activities relevant to the problem.

In a complex situation such as the USG, there are stakeholders with differing perspectives and value systems, and divergent views on activities that best assure the region's future. For example, the resource sector may view supply of refined ores and steel production as being the key to the region's prosperity and jobs, while industry would focus on provision of fabrication, maintenance and safety services to mines. Conservationists and the tourist sector may most value preservation of the natural environment and species (e.g. cuttlefish, seascape and landscape). Resident groups, such as elderly citizens, may value the lifestyle and amenity of the region, and view aged care, health services, retail and cultural facilities as a priority.

As Jackson (2006) has noted, the strength of critical systems thinking and SSM is in bringing forth divergent values, beliefs and worldviews on a problem situation. These are recognised and reflected in various root definitions and transformation statements, which can then be debated and attempts made to develop an overall transformation statement that reconciles various views and goals.

For the purposes of demonstrating the methodology, it is argued that the USG expects to transform from a 'dirty' and highly resource intensive region ('The Iron Triangle'), where resources are simply dug out of the ground and exported, to one which is clean, low carbon and resilient, with more value-adding enterprises and services to capitalise fully on its abundant resources. Whilst the mining and export of ores and minerals heralds a promising future for the USG, much can be gained by value-adding to these products and commodities.

Such a transformation is already envisaged by the Global Maintenance USG, which is exploring opportunities for clusters of small to medium size enterprises to provide services to mining companies e.g. fabrication, testing, cleaning services and the like. Global Maintenance is an organisation that draws its membership from businesses across the Upper Spencer Gulf region involved in engineering and maintenance services to the resource processing sector. It was established to promote the Upper Spencer Gulf as a regional centre of excellence in the provision of 'maintenance services' to the local, national and international resource processing sector. The aim is to have the Upper Spencer Gulf region recognised as suppliers to the global resource sector, and to show that our businesses are working together and contributing to the region's economic growth and community strength (Global Maintenance USG, 2012).

4.3 Collaboration and capability networks ('how do we get there?')

Stakeholder groups or 'collaborative networks' may be formed with (desirably) a common understanding of *what* is needed to engage with the identified problems and to achieve the desired transformation. Needs, competencies, and resources can be matched to form 'capability networks', assisted by interaction mapping (Morelli, 2006). The main purpose of the process is to explore and facilitate synergistic relationships within the stakeholder group and beyond.

A 'solution oriented partnership' (SOP) created by the convergence of different stakeholders, including 'customers', 'actors' and 'owners', can now explore *how* community transformation may be attained, utilising their inherent strengths and building upon their joint competencies and resources in the 'capability networks'. This will include identifying other competencies, resources, infrastructure and enabling mechanisms that may be required to develop and deliver solutions, while considering the mix of products and services that may assist the transformation.

The previously mentioned Upper Spencer Gulf Common Purpose Group (CPG) is an example of such a stakeholder group and SOP. Membership comprised mayors and chief executive officers (CEOs) of the three local governments, the CEOs of the three Regional Development Boards, and one representative from each of the combined Chambers of Commerce, trade unions, the Whyalla Campus of the University of South Australia, and the Spencer Institute of Technical and Further Education (Cheers et al., 2002). As the authors noted, there has been extensive study of dynamic 'network' regions, involving vigorous intra and inter-sectoral partnerships, holistic systems approaches to leveraging the maximum benefit from finite human, technological, economic and community resources within a region. They refer to encouraging co-operation between players to reduce overheads and transaction costs (as in shared incubator facilities), win business (clustering) and new cooperative production; the presence of innovative research and development and technical expertise in a region is always regarded as essential (Cheers et al., 2002, 13).

4.4 Service solutions and PSS mode development ('what do we need to get there?')

Such a strategic partnership, coupled with the product and service competencies of the actors as well as physical and non-physical resources involved, may be manifested in 'product-service modes', consisting of scenarios, task forces and product-service configurations, as illustrated earlier in Figure 2, and especially when these are viewed holistically and inter-connected.

a) A more resourceful region: closing the loop

Industrial ecology initiatives are emerging in the region, fostered by the SA Government's 'eco-innovation program'. Major industry companies across the USG are examining synergies in their operations and how they may improve co-operation and hence efficiency in their use of materials, energy, water and minimise waste.

At an enterprise level, in an effort to reduce energy in its steel production, OneSteel is replacing a significant proportion of the coke normally used in steel making with recycled tyres of plastics that are rich in carbon, with the assistance of researchers at the University of NSW (2012). The technology, called Polymer Injection Technology, has been patented internationally. In PSS terms, the tyre companies find new profit centres by providing a 'fuel service' to the steel industry, which may in future provide steel services for customers.

The Nyrstar lead smelter in Port Pirie has a partnership with the local council whereby it treats water used through the plant for its own reuse and use by the council for watering public spaces (Kellett et al., 2011).

Of potential relevance to the USG and especially its power station, the Australian Algal Fuels Consortium is developing a pilot-scale second generation bio refinery for sustainable micro algal bio fuels and value added products. The project is to be located at Torrens Island, South Australia, and uses captured flue gases and carbon dioxide from the adjacent power station (Nayar and Thomas, 2010). Again, in PSS terms, the power company (AGL) may provide electricity or energy efficiency services to customers, while Algal Fuels can provide a carbon capture service to AGL combined with bio product services to other customers (e.g. biodiesel), Under the Australian carbon price legislation, this will have mutual benefits – offsetting AGL emissions, generating carbon credits for Algal Fuels and a low cost and sustainable fuel service for its customers.

According to Coleman, cited by Spinks (2012), algae are versatile and adaptable and can be grown anywhere there is sunlight and water. ‘Areas that are too dry, too hot, or too cold to support trees or other plants can still potentially be used for algae. Deserts are an obvious place for algae farms, since the land cannot be used for much else and there is plenty of sunlight. The issue there is providing water and other nutrients — nitrogen, phosphorus, potassium and iron. But this is not difficult using a closed system where the water is trapped, and cannot evaporate’.

Applying PSS theory, and consistent with the above transformation statement, one may envisage a future where the resources sector provides product-services to global customer markets, transforming businesses from selling resources to providing resource services and exercising product stewardship. For example, companies could provide uranium energy services, taking back and reusing uranium waste. Similarly, USG manufacturing companies could provide their products as part of services to the resource sector and others, again opening up new profit pools (see Gadiesh and Gilbert, 1998).

b) Farming and fishing industry

Wheat, barley, wool, sheep, cattle and grain legumes have provided a strong economic base for the region, with aquaculture having been developed recently near Port Augusta and Whyalla. Commercial fisheries continue in the Spencer Gulf, although catch tonnage is decreasing and impacted by the establishment of marine reserves.

As noted by O’Brien et al. (2008), there is potential for farming activities to reduce agricultural emissions and increase sequestration of carbon in biomass. The development of biomass energy crops will enable diversification of farm operations in conjunction with ongoing food production. This is also recognised by Australia’s plan for a ‘Clean Energy Future’ (see Australian Government, 2011a, b).

In addition, aquaculture is an emerging industry in the USG. There is the potential for ‘integrated multi-trophic aquaculture’ (IMTA), whereby different aquaculture species are farmed together in a way that allows one species’ wastes to be recycled as feed for another. This approach, which is much akin to industrial ecology, is being piloted in parts of Canada; it provides economic diversification and increases the acceptability of the aquaculture sector. As Chopin (2006) has noted, the goods and services provided by bio filtering organisms have finally been recognised and valued for their eco-system function.

c) Natural environment and eco-tourism

The region is also seeking to capitalise on its environmental advantages, with groups promoting a clean green image for the cities, especially as the region is the gateway and service centre to the Eyre Peninsula, Flinders Ranges and Outback.

Tens of thousands of giant cuttlefish head to the Whyalla region each winter to breed, which has become a tourist attraction. Their annual ritual has also become a pivotal environmental argument against BHP Billiton's coastal desalination plant at the Point Lowly peninsula, which is part of its planned expansion of the Olympic Dam mine. Research has found the cuttlefish population is already in serious decline ahead of hyper-saline brine being pumped from the future plant into Spencer Gulf (Kennett and Crouch, 2012).

A resident survey conducted by Petkov (2008) highlighted opposition to the Point Lowly development, with comments including: 'The Peninsula should be promoted for tourism. Overseas visitors comment on the beauty of the area'. 'There should be more to Whyalla than just mining and industrial activities'. Respondents were concerned about the fragility of the area and the loss of what is regarded as the last site of aesthetic beauty in the area.

Thus, a scenario can be envisaged whereby the USG can strengthen its role as a gateway and service centre for regional eco-tourism, including the indigenous cultural experience.

d) Water use efficiency

To alleviate pressures on its availability for industry and the USG communities, it is critical that water is used more efficiently, with piped water supply being supplemented by rainwater harvesting and desalination.

Hitherto, drinking quality water from the pipeline has been used for industrial purposes, but there is now a realisation that this is an inefficient use of a precious resource. After its first use for drinking and washing, water has second uses such as dust suppression and toilet flushing.

OneSteel has installed a seawater reverse osmosis desalination plant to assist with operations at its Whyalla steelworks, while a 200 megalitre per day plant is planned to provide water via a 320km pipeline to the expanded Olympic Dam mine. However, desalination not only consumes significant energy but also discharges high density brine that poses a threat to marine species, including the above-mentioned cuttlefish. A consolidated and shared plant may offer efficiencies by satisfying the demand of several industries, while waste heat from industry (e.g. the steelworks) may provide energy for thermal desalination (distillation) processes.

A scenario may be envisaged whereby industry and the community enjoy a symbiotic relationship in use of water. For example, treated grey water from industries such as the Whyalla steelworks and iron ore processing facility could be considered for community use, such as in the previously mentioned partnership involving Nyrstar and the City of Port Pirie, with possibilities for industry to assist with provision of community water infrastructure.

e) Renewable energy

The region is also well placed to capitalise on its abundant sunlight and other renewable energy resources, to reduce its dependence on fossil fuels, especially given Australia's introduction of a carbon price.

Schneider (2006) envisaged the State's energy demand could be met increasingly by establishing hubs of renewable energy in regional areas such as the USG, combining (where possible) solar, wind, geothermal and carbon capture and storage technologies, and optimising the use of the high voltage transmission system that runs from Port Augusta to Adelaide. Reflecting resource efficiency principles, he noted that combining energy sources in hubs would create economy of scale, ensuring that the often prohibitive cost of infrastructure, particularly transmission lines, could be shared between proponents.

Alinta Energy is exploring the idea of converting its Port Augusta Power Stations into solar thermal facilities. The power station conversion was first proposed by renewable energy advocate, Beyond Zero Emissions (BZE), which envisages Port Augusta as an 'iconic global hub for base load solar power generation'. As BZE (2012) has explained, concentrating Solar Thermal (CST) power involves capturing the USG's abundant solar energy to create heat, and create electricity using the generated heat. Solar thermal plants are similar to coal plants, using a steam cycle to convert heat into electricity. Furthermore, solar thermal can be integrated into the existing power station, using existing infrastructure and pre-heating boilers in the same way that a solar booster plant will be designed to do. Instead of burning coal, they use mirrors to concentrate the sun's energy. A key attribute of solar thermal technology is the ability to readily incorporate storage technologies. BZE claims the project would ensure continued employment of existing workers at local power stations, create 1300 construction jobs and 225 manufacturing jobs (Energy Matters, 2012).

Gas conversion is also under consideration, but there is no gas in Port Augusta so a gas pipeline would be required. The solar thermal proposal has gained strong support by Port Augusta locals and leaders (BZE, 2012; Energy Matters, 2012), with Ms Baluch, the mayor of Port Augusta, stating: 'We need to see solar thermal energy developed in South Australia and for us to become world leaders in this renewable energy. Certainly gas is not the answer' (Baluch, cited by Gage, 2012).

The first large scale solar thermal facility in Australia, 'Solar Oasis', is expected to begin construction soon in Whyalla (Parkinson, 2012). The 40MW project will comprise about 330 'big dish' solar thermal concentrators, which each have 500 square metres of high technology mirrors capable of generating temperatures in excess of 1500 degrees centigrade. Unlike the Port Augusta solar thermal proposal that will store energy, the solar farm is designed to be a 'peaking power plant' that will generate electricity when it is most in demand. Energy will be concentrated onto a receiver to produce super critical hot steam that will drive a turbine to produce electricity. Importantly, the dishes will be manufactured and assembled on-site using a 'factory in the field', resulting in the direct generation of over 200 local jobs during the two year manufacturing and construction period, with additional opportunities during ongoing operation and maintenance.

Further opportunities are being explored, in the region and elsewhere, for solar photovoltaic panels and even thin film to be integrated with steel roofing. Such initiatives would enable Whyalla and other cities in the USG to use residential and other buildings as generators of renewable energy, to be fed into the energy grid.

Thus, the scenario of a renewable energy future for the USG is already well developed.

4.5 Example of PSS mode: renewable energy

In this section, the theme of renewable energy is explored in more depth to illustrate how a PSS scenario may be developed to provide the communities in the region with improved and more efficient access to electricity through interaction of product (energy facilities/equipment), energy services (power generation, supply, customer relationships, management), and various stakeholders and resources.

In 1999, electricity supply in South Australia was privatised and split into generation, distribution and retail; however, there may be benefits in reintegrating, especially on a regional basis. Alinta Energy operates coal- and gas-fired power stations (including a co-generation plant at New Zealand Steel's steelworks) and is the largest retailer of natural gas in Western Australia, supplying gas and electricity to residential customers, major resource projects and commercial and industrial loads. Such experience can only assist in building a regional energy strategy.

a) Task force

A portfolio of electricity generators comprising wind and solar generators from Eyre Peninsula and geothermal producers from northern South Australia, backed up by gas-powered generation could maximise use of intermittent renewable energy, while guaranteeing supply to customers. Furthermore, an integrated energy company may form collaborations between large (power stations), small (solar or wind farms) and micro generators (household solar panel installations) to improve energy distribution across a grid, with renewable energy hubs as envisaged by Schneider (2006). This could represent the basis of a task force as explained in Figure 2, while other actors may include households, local councils, groups such as BZE, the federal government via its Renewable Energy Development Program, and universities and research institutes. Each entity would contribute its specific product and service competencies. For example, the University of South Australia could contribute specific research and testing expertise in solar thermal technologies and smart grids via its sustainable energy group.

b) Product-service configuration

The product-service configuration is the specific technical and service solution targeted at improving; energy efficiency, network efficiency or the amount of renewable energy supplied. By examining the synergies in product and service competencies within the taskforce, as well as the resources and infrastructures, energy produced by centralised power stations could be supplemented by solar panels installed on consumer houses as part of solar energy services.

As another element of this configuration, RFID technology and the internet can be used to provide real time data on the performance of solar panels, with problems being identified and service technicians alerted. Furthermore, the solar panels could be designed in modules for ease of take-back, disassembly and re-manufacturing, supported by business models such as renting and leasing and financial schemes such as pay for use (see Mont, 2001). Importantly, the customers would not actually own the panels. The energy company would undertake this role, or a third-party installer or financier could own and maintain the panels and sell the electricity they generate back to the customer. Such elements all form part of the PSS configuration, supported by infrastructure such as a smart electricity grid.

Figure 3 presents a schematic view of such a PSS mode development - an example of PSS for durable customer products (Mont, 2001).

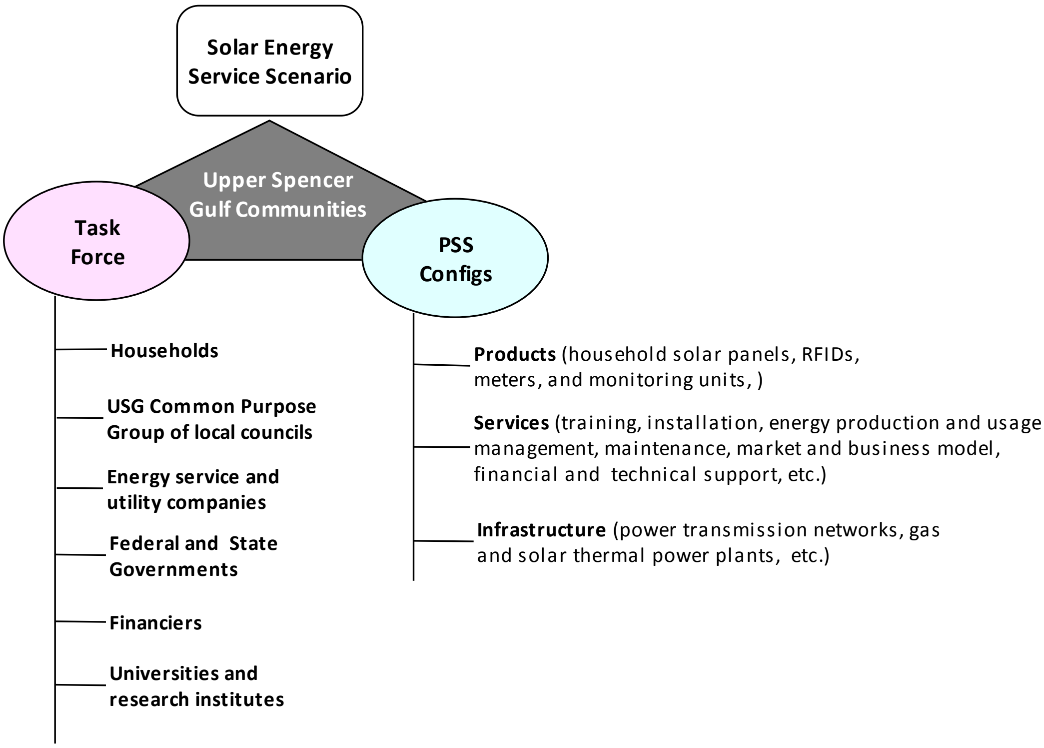

Figure 3. A PSS mode for solar energy service scenario

Further collaboration with industry and householders may develop a virtual power plant, whereby energy savings and demand shifts effectively create new generation without new construction. Energy could be provided to customers by an energy service company (ESCO). An ESCO is an organisation that seeks to improve energy efficiency for customers in order to reduce the energy costs by developing, installing and financing comprehensive performance based projects and solutions, using the efficiencies gained to pay for the full cost of its measures (see Kellett, 2007). Similarly, as Mont (2001) explained, a PSS utility model comprises activities that are aimed at reducing overall energy consumption. For example, the company may offer a system solution to customers, extending to demand side management whereby the company builds and supplies meters to customers to monitor energy use in the business or home, enabling them to prioritise measures to reduce electricity bills. As Vine et al. (1999) have explained, ESCOs may partner with utility companies in some circumstances, although ESCOs and utilities often view each other as competitors.

As preliminary research by Ness et al. (2005) indicated, such PSS solutions may offer not only environmental benefits such as reduced waste and emissions, but also financial benefits and new profit centres for producers and cost savings and improved service for customers: a series of potential ‘win-wins’.

4.6 Holistic consideration

Various scenarios and PSS modes can now be considered holistically, across a ‘solution oriented partnership’, identifying further connections and synergies that benefit a number of stakeholders.

It may be possible to gain general support for a vision of the USG that involves its transformation to a low carbon emission future. Latrobe City Council, Victoria (centre of a large fossil fuel power industry) has developed a policy to position and prepare the municipality to prosper in such a future (Latrobe City, 2010). This recognises that agricultural projects and renewable energy schemes may generate carbon credits and sell these into the carbon market, fostering the development of manufacturing and service based industries within Latrobe City.

Such a vision could integrate a number of the scenarios and PSS modes discussed above and illustrated in Figure 2. Renewable energy provision, such as via the PSS examples above, could have positive implications for the manufacturing sector in the USG, opening up new business opportunities in the manufacture, maintenance and remanufacture of solar panels and 'big dish' solar collectors, where the components are kept in 'closed loops'. Steel manufacturing may be streamlined with new digital and other monitoring technologies and service-oriented business models, while the region may be a hub for niche value-added manufacturing, especially with small-medium enterprises (SMEs), along the lines of what Roos (2012) has proposed. Thus, manufacturers may find new roles and profit centres by becoming service providers. Furthermore, the University of SA's Whyalla Campus could, in partnership with the technical and further education sector, industry and others, offer special programs and education services tailored to a clean, green and smart economy.

Moreover, renewable energy could not only provide a clean power source for industry and the community but also create saleable carbon credits. Similarly, carbon sequestration in agriculture and tree planting may also generate carbon credits, improve the quality of soils and landscapes, and have other co-benefits for eco-tourism and food production. One may envisage co-benefits for the tourism sector, with renewable energy technologies being showcased to visitors.

Taking a wider view, the future of the USG can be viewed in context of its relationship with the manufacturing giants and commodities markets of China and India. For example, China (and India) has enormous market potential and investment capital, while SA has natural resources, services and technology expertise in areas critical to China's continued growth, with SA also 'perfectly positioned to be a long-term, reliable supplier to meet China's minerals and energy security needs' (Government of SA, 2012a, 16). There is an opportunity to build upon relationships based upon resources and energy to develop partnerships on sustainable environmental practices, food services (e.g. high quality seafood), planning of industrial and coastal areas, tourism, education and much more. This could involve China taking equity positions or forming joint ventures in agribusinesses and export linked agriculture (Government of SA, 2012) – product-service partnerships rather than ownership of land and resources.

5. Discussion

The above examples have illustrated how, using the model and symbiotic planning principles, the USG may be transformed to clean, low carbon and resilient region, with more value-adding enterprises and services. Further research is required to test the propositions and ideas put forward, in conjunction with the USG Common Purpose Group (CPG).

For the future vision to be realised, it is critical for the stakeholders and groups to ask how their mutual objectives may be better served by working together, preferably via the CPG, Global Maintenance USG and similar existing initiatives and institutions. This can involve agreeing upon a 'transformation statement', connecting efforts across sectors, establishing clusters, building upon existing initiatives and regional strengths, and establishing an integrated governance framework and set of strategies and policy instruments.

This is consistent with the strategies proposed by Roos (2012) for South Australia's manufacturing future. As Roos said, 'there is substantial evidence to suggest that innovation and economic growth are heavily geographically concentrated so clusters provide an environment that is conducive to both innovation and knowledge creation (Roos, 2012, 15). He proposed ‘creative regions’, referring to knowledge creation in a region that is not sector specific: ‘this occurs due to the presence of a variety of skills and competencies that interact in an unplanned manner and hence generate new and often unforeseen knowledge that can be embodied in product-service systems, designs and business models’ (Roos, 2012, 14). Groups of linked actors (firms, financial actors, public actors, universities etc) could be clustered, with the group’s competitive advantage being grounded in resources (monetary, physical, relational, organisational and human) linked to a particular location. Such thinking is reflected in the proposed model and exemplified by the symbiotic approach to planning of the USG.

This is important not only for the USG region and its people, but also for South Australia/Australia’s prosperity, and for establishing co-operative relationships with Asia towards a clean energy and sustainable future (see Government of SA, 2012).

However, integrated governance of the Upper Spencer Gulf will be difficult due to the separate Regional Plans covering the three cities and their hinterland. Other barriers include the focus on export of resources, such that closing a life cycle loop is not considered, and competition and secrecy among resource companies, requiring a change in corporate culture to foster collaboration. A legal framework is required, so that collaboration is not viewed as collusion and the final responsibility for reused materials is identified. A further barrier is the change in provider and customer mindsets required to shift from a purchase and sale regime to one that involves continuing relationships based upon services.

6. Closing comments

The ‘Triple Helix’ cooperation established in Sweden, utilising the complementary expertise and skills of academia, industry and government, may extend to multi-national cooperation, sharing and promulgation of such approaches that are of critical importance in addressing Global challenges of sustainable development.

Sweden has already established cooperation with China, exploring how the East Sweden industrial symbiosis experiences may benefit the Tianjin Eco-Industrial Zone (Baas, 2011). This could be further extended to include regions such as the USG, South Australia, followed by multi-national studies, sharing of experiences and benchmarking involving regions within EU, USA, Australia, China and India.

Further research is required, extending the work of UNESCAP (2011, 73-78) regarding resource efficiency indicators and indices, to evaluate and measure how the symbiotic approach put forward may lead to improved and multiple sustainability benefits, when compared with business as usual ‘silo’ approaches.

References

Australian Government, 2011a. Clean Energy Future: Fact Sheet – Regional Australia http://www.cleanenergyfuture.gov.au/regional-australia/

Australian Government, 2011b. Clean Energy Future: Fact Sheet – Carbon Farming http://www.cleanenergyfuture.gov.au/carbon-farming-initiative/

Australian Government, 2010. *Regional Employment Plan: Port Augusta-Whyalla-Port Pirie Priority Employment Area* http://www.deewr.gov.au/Employment/Programs/PEA/Documents/PortAugusta.pdf

Ayers, R., 1999. *Products as service carriers: should we kill the messenger – or send it back?* Zero Emissions Forum, UN University, Tokyo.

Baas, L., 2011. The challenge of industrial ecology for a sustainable economy in China, in *The green economy and its implementation in China*, Liu, M, Huang, H and Ness, D (eds), Enrich Professional Publishing, Singapore, pp.101-120.

BHP Billiton, 2011. Olympic Dam Expansion 2011. http://www.bhpbilliton.com/home/aboutus/regulatory/Documents/Olympic%20Dam%20Supplementary%20EIS/Information%20Sheets/BHP%20Billiton%20Olympic%20Dam%20Expansion%202011%20Summary%20Booklet.pdf

BZE, 2012. Repowering Port Augusta, Beyond Zero Emissions. http://media.beyondzeroemissions.org/Repowering_PortAugusta.pdf

Checkland, P., 2001. Soft systems methodology, in Rosenhead, J & Mingers, J (eds), *Rational analysis for a problematic world revisited: problem structuring methods for complexity, uncertainty and conflict*, 2nd edition, John Wiley and Sons Ltd.

Cheers B., Harvey J., Clarke, R., Heffernan, P., 2002. *The Upper Spencer Gulf Common Purpose Group: a model of Intra-regional cooperation for economic development*, Centre for Rural and Regional Development, University of South Australia, 30 August.

Chertow, R., 2000. Industrial symbiosis: literature and taxonomy, *Annual Review of Energy and Environment*, 25, 313-337. http://www.annualreviews.org/doi/pdf/10.1146/annurev.energy.25.1.313

Chopin, T., 2006. Integrated multi-trophic aquaculture: what it is and why you should care, *Northern Aquaculture*, July/August. http://irrec.ifas.ufl.edu/teachaquaculture/curriculum/_files/modules/8_plants/Handouts/Chopin%202006%20IMTA%20Global%20Aquaculture%20Advocate.pdf

Collins Dictionary, 1995.

Corning, P. A., 1998. The Synergism Hypothesis: On the Concept of Synergy and Its role in Evolution of Complex System, *Journal of Social and Evolutionary Systems,* vol 21(2), accessed via http://www.complexsystems.org/publications/synhypo.html on 8 February 2011.

Ehrenfield, J., and Gertler, N., 1997. Industrial ecology in practice: the evolution of interdependence at Kalundborg, *Journal of Industrial Ecology*, Vol 1, Number 1, 67-79.

Energy Matters, 2012. Repowering Port Augusta with Solar and Wind – Blueprint, 20 April. http://www.energymatters.com.au/index.php?main_page=news_article&article_id=3171

Gadesh, O., Gilbert, J., 1998. Profit pools: a fresh look at strategy, *Harvard Business Review*, May-June, 139-147.

Gage, N., 2012. Federal Govt under pressure to close polluting power stations, ABC, 19 April. http://www.abc.net.au/am/content/2012/s3480713.htm

Global Maintenance USG, 2012. Company overview. (http://www.gmusg.com/Current/?curpage=CompanyOverview, accessed 28 April 2012).

Government of SA, 2012. *South Australia-China Partnership: a Shared Future*, Dept for Manufacturing, Innovation, Trade, Resources and Energy in conjunction with Australia China Business Council SA Chapter, April. http://www.dmitre.sa.gov.au/trade/china_strategy/china_directions_paper

Government of SA, 2005. Strategic Infrastructure Plan for South Australia: Regional Overview, May http://www.infrastructure.sa.gov.au/__data/assets/pdf_file/0004/5179/3_UPPER_SPENCER_GULF_and_OUTBACK_14-25.pdf

Harvey, J., Cheers, B., 2011. The Upper Spencer Gulf Common Purpose Group: a model of intra-regional cooperation for economic development, in *Governance and Planning of Mega-city Regions: an International Comparative Perspective, Routledge Studies in Human Geography*, Routledge, Abbington, Oxon, 191-210.

Jackson, M. C., 2006. Creative holism: a critical systems approach to complex problem situations, *Systems Research and Behavioural Science*, 23, 647-657.

Jégou, F., Joore, P., 2004. *Food delivery solutions. Cases of solution oriented partnership*, Cranfield University, UK.

Kellett, J., 2007, Community-based energy policy: a practical approach to carbon reduction, *Journal of Environmental Planning and Management*, 50:3, 381-396.

Kellett, J., Ness, D., Hamilton, C., Pullen, S., Leditschke, A, 2011. *Learning from Regional Climate Analogues*, National Climate Change Adaptation Research Facility, Gold Coast, 166p. http://www.nccarf.edu.au/content/learning-regional-climate-analogues

Kennett, Heather and Crouch, Brad (2012), Cuttlefish population in decline, *AdelaideNow*, 2 June. http://www.adelaidenow.com.au/news/south-australia/cuttlefish-population-in-decline-bhp/story-e6frea83-1226381517382

Krucken, L., Meroni, A., 2006. Building stakeholder networks to develop and deliver product-service-systems: practical experiences on elaborating pro-active materials for communication, *Jnl of Cleaner Production*, 14, 1502-1508.

Latrobe City, 2010. Positioning Latrobe City for a Low Carbon Emission Future, 6 April. http://www.latrobe.vic.gov.au/WebFiles/EcoDev/Positioning%20LC%20for%20a%20Low%20Carbon%20Emissions%20Future%20Policy%206%20April%20CM.pdf

Lay, G.Schroeter, M., Biege, S., 2009. Service-based Business Concepts: a Typology for Business-to-Business Market, *European Management Journal*, Vol.27, 442-455.

Littley, B., 2012. Clean up or go, *The Advertiser*, 27 July.

Manzini, E., Vezzoli, C., 2003. A strategic design approach to develop sustainable product-service systems: examples taken from the 'environmentally friendly innovation' Italian prize, *Jnl of Cleaner Production* 11, 851-857.

Manzini, E., Collina, L., Evan, S., 2004.*Solution oriented partnership, How to design industrialised sustainable solutions*, Cranfield University, UK.

Maussang, N., Zwolinski, P., Brissaud, D., 2009. Product-service system design methodology: from the PSS - architecture design to the products specifications. *Journal of Engineering Design*, 20(4), 349.

Mirata, M., Tareq, E., 2005. Industrial symbiosis networks and the contribution to environmental innovation: the case of the Landskrona Industrial Symbiosis Programme, *Journal of Cleaner Production*, 13, 993-1002.

Mont, O., 2001. Introducing and developing a Product-Service System (PSS) concept in Sweden, *IIIEE Reports 2001: 6*, Lund University, Sweden.

Mont, O., 2004. Product-Service Systems: Panacea or Myth? *IIIEE*, Lund University, Sweden, p.259.

Morelli, N., 2006. Developing new product-service systems (PSS): methodologies and operational tools, *Journal of Cleaner Production* 14, 1495-1501.

Nayar, S., Thomas, R., 2010. Pilot-scale bio refinery for micro algal bio fuels and co-products, *AusBiotech 2010*. http://ausbiotech2010.com.au/uploads/Speaker%20presentations/Sasi%20Nayar%20public%20version.pdf

Ness, D., Clement, S., Field, M., Filar, J., Pullen, S., 2005 '(Approaches towards) sustainability in the built environment through dematerialization', in *Proceedings of World Sustainable Building Conference*, Tokyo, September.

Ness, D., 2011. Ascending Jin Shan together: standing high, looking far, we can achieve a green economy and more, in *The green economy and its implementation in China*, Liu, M., Huang, H., Ness, D. (eds), Enrich Professional Publishing, Singapore, 359-378.

O'Brien, N., Meizlish, M., Hawn, H., 2008. *Carbon Trading and Renewable Energy: a Discussion Paper on Carbon Credits and Bioenergy Developments for Forestry and Agricul*ture, Rural Industries Research and Development Corporation and Bioenergy Australia, Canberra, 24 November. https://rirdc.infoservices.com.au/items/08-184

Parkinson, G., 2012. $230m Whyalla solar dish project signs funding deal, *Reneweconomy*, 21 March. http://reneweconomy.com.au/2012/230m-whyalla-solar-dish-project-signs-funding-deed-66538

Partidário, P., Lambert, J., Evans, S., 2007. Building more sustainable solutions in production-consumption systems: the case for people with reduced access, in *Jnl of Cleaner Production* 15, 513-524.

Pawar, K. S., Beltagui, A., Riedel, J.C.K.H., 2009. The PSO Triangle: Designing Product, Service, and Organisation to Create Value, *International Journal of Operations and Production Management*, vol 29(5), 468-493.

Petkov, J., 2008. *Survey results: development of Point Lowly*, Applied Statistics Unit, University of SA.

Ramsay, R., 2011. *Ramsay calls on full compensation for OneSteel and Nyrstar plants*, media release, 20 June.

Ramirez, R., 1999. Value co-production: intellectual origins and implications for practice and research, *Strategic Management Journal*, 20, 49-65.

Regional Development Australia, 2012. *What we do* (http://rda.gov.au/node/11, accessed 23 July 2012).

Reijnders, L., 1998. The Factor X debate: setting targets for eco-efficiency, *Journal of Industrial Ecology*, Vol 2, No 1, 13-22. http://onlinelibrary.wiley.com/doi/10.1162/jiec.1998.2.1.13/pdf

Ritthoff, M., Holger, R., Liedtke, C., 2002. *Calculating MIPS: Resource Productivity of Products and Services*, Wuppertal Institute for Climate, Environment and Energy.

Roos, G., 2012. *Manufacturing into the Future*, Adelaide Thinker in Residence 2010-2011, Government of South Australia. http://www.thinkers.sa.gov.au/thinkers/roos/report.aspx

Schneider, S., 2006. *Climate Change: Risks and Opportunities*, Report of Adelaide Thinker in Residence, December. http://www.thinkers.sa.gov.au/thinkers/schneider/report.aspx

Schmidt-Bleek, F., 2000. *The Factor 10/MIPS-Concept Bridging Ecological, Economic, and Social Dimensions with Sustainability Indicators*, The Factor 10 Institute. http://www.factor10-institute.org/files/MIPS.pdf

Spinks, P., 2012. Plugging into algal power, *Whyalla News*, 13 March. http://www.whyallanewsonline.com.au/news/national/national/general/plugging-into-algal-power/2485549.aspx?storypage=1

Tilley, D. R., 2003. Industrial ecology and ecological engineering: opportunities for symbiosis, *Journal of Industrial Ecology*, Volume 7, Number 2, 13-32.

UNESCAP, 2011. *Are we building competitive and liveable cities? Guidelines for developing eco-efficient and socially inclusive infrastructure*, pp.125, Environment and Development Division, United Nations Publication, Bangkok, accessed via http://www.unescap.org/esd/environment/infra/documents/Guidelines.pdf on 23 November 2011

University of NSW, 2012. *'Green steel' from old rubber tyres produces no waste or toxic fumes*, Centre for Sustainable Materials Research and Technology, 16 May.

Van Halen, C., Vezzoli, C., Wimmer, R., 2005. *Methodology for Product Service Innovation: How to Develop Clean, Clever and Competitive Strategies for Companies*, Netherlands: Koninklijke Van Gorcum.

Vine, E., Nakagami, H., Murakoshi, C., 1999, The evolution of the US energy service company (ESCO) industry: from ESCO to super ESCO, *Energy* 24, 479-492.

von Weizsäcker, E., Lovins, A. B., Lovins, L. H., 1998. *Factor four: doubling wealth, halving resources*, Earthscan.

von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C., Stasinopoulos, P., 2009. *Factor 5: Transforming the Global Economy through 80% Increase in Resource Productivity*, Earthscan, UK and Droemer, Germany.

Wallbaum, H., Buerkin, C., 2003. Concepts and instruments for a sustainable construction sector, *UNEP Industry and Environment*, April-September, 53-57.