Measuring sustainability performance in Industrial parks: A Case Study of the Kwinana Industrial Area

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Abstract

Industrial parks/areas are increasingly required to substantiate their environmental and sustainability performance with increasing pressures from both government and the community. In order to address these pressures the Kwinana Industrial Area have started the development of a Sustainability Roadmap centred on a set of sustainability indicators developed through proactive and collaborative engagement involving all the industries in the industrial park together with the local community. Many of the currently available sustainability assessment frameworks have been tested at a national, state or organisational level, but have not yet found application in industrial areas and so-called 'eco-industrial parks'. This paper discusses the early development of a Sustainability Roadmap for the Kwinana Industrial Area through the development of a matrix of sustainability indicators chosen and ratified by both industry players and the community hosting the industrial area.

Keywords

Eco-industrial parks, performance indicators, sustainability indicators, sustainable development, community engagement, industrial symbiosis, sustainability metrics.

Biographical notes

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1. Introduction

The concept of industrial ecology (Schwarz and Steininger, 1997, Sterr and Ott, 2004)was developed in the early 1990'swith the intent of describing and evaluating industry-environment interactions based on a systems perspective (Chertow, Ashton and Espinosa, 2008) and the value of these systems in improving sustainability and environmental performance. Within industrial ecology, industrial symbiosis focuses on the flow of resources through clusters of geographically proximate businesses and the sharing of information, services, utility, and by-product resources among one or more industrial producers in order to add value, reduce costs and importantly improve environmental impacts. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by co-located firms (Chertow, 2000).Industrial symbiosis collectively optimizes material and energy use at efficiencies beyond those achievable by any individual process alone. Many of the benefits of industrial symbiosis are related to subjects that have been considered within other disciplines including sustainable development, eco-efficiency, pollution prevention, cleaner production and waste minimisation (CECP 2007).

Building on industrial symbiosis the term 'Eco-industrial park'was then established to describe those industrial parks that focus on the collective improvement of their environmental and sustainability performance, usually through the management of industrial symbiosis programs. The definition of this term however, is broad and still in development (Chertow, 2000, Peck, 2002). According to a widely accepted definition, an Eco-industrial park is *"a community of businesses that collaborate with each other and with the local community to efficiently share resources (information, materials, water, energy, infrastructure and natural habitat), leading to economic gains, gain in environmental quality, and equitable enhancement of human resources for the business and local community"*(Lambert and Boons, 2002 p472). The gains in efficiency, savings in resources and improvements in governmental/community interaction associated with industrial symbiosis programs are commonly referred to as 'regional synergies'.

Lambert and Boons (2002) distinguish between three major Eco-industrial park categories:

i. Industrial complexes: geographically concentrated industrial activities, mainly process industries, with tight couplings of a relatively small number of materials and energy intensive production processes (e.g. Kalundborg, Denmark).
ii. Mixed industrial parks: industrial activities, mainly SMEs, which are concentrated in dedicated areas, of a very diverse nature with no or little coupling of production processes (Burnside near Dartmouth; Nova Scotia, Canada).
iii. Eco-industrial regions or virtual Eco-industrial parks: industrial activities in a larger geographical or administrative area, usually referring to a diversity of industries, but often with a definite specialisation.

Other categories that can be included in this definition are (Haskins, 2007):

- Recycling business clusters,
- Collection of firms making "green" products,
- Solar-energy driven park and
- Parks with environmentally friendly infrastructure or construction.

Increasingly industrial areas are seeking to define themselves as 'Eco-industrial parks' claiming enhanced competitive advantages for potential investors and less environmental impacts on the adjacent community (Lambert and Boons, 2007). As a result, Eco-industrial park promotion is often challenged justifying these claims. While the concepts of industrial symbiosis and Eco-industrial park provide the opportunity to advance the sustainable development of an industrial region, it is necessary to find appropriate performance measures to substantiate the sustainability measures claimed. Efforts to establish sustainability indicator systems specifically for Eco-industrial parks are still in the early stages of development (Cote, 2008; Lowe, 2001; Schianetz*et al.* 2008).These systems should:

i. Guide strategic decision making on the long-term sustainability of the industrial area, and assist in the definition of sustainability policies and aspirational targets;
ii. Provide the basis for stakeholder discussions on sustainable development of the industrial area/Eco-industrial park, including emerging issues and possible future directions;
iii. Scope sustainable development initiatives (e.g. research projects, feasibility studies) for the industrial area/Eco-industrial park, which would assist the participating industries in achieving their aspirational targets;
iv. Document progress towards sustainability goals and targets; and
v. Provide a historical perspective on the past milestones achieved by the industrial area/Eco-industrial park participants.

The Kwinana Industrial Area (KIA) in Western Australia is one of the largest documented Eco-industrial parks in the world (CECP, 2007; Schianetz *et al.* 2008). 47 regional synergies are already in place in the KIA, 32 of these are by-product synergies and 15 involve shared use of utility infrastructure. The existing regional synergy projects in Kwinana greatly exceed 'business-as-usual', and are more diverse and significant than reported for other heavy industrial areas (CECP, 2007). This positions Kwinana among the international leading edge examples of industrial symbiosis (regional synergy) development. The benefits of existing synergies in Kwinana have gone well beyond the conventional benefits of reduced operational costs and have included substantial sustainability management benefits including support for resource security, increased operating efficiency, reduced landfill disposal and improved community relationships.

The development of a Sustainability Roadmap is the next step for the KIA in further developing its sustainability credentials as a leading Eco-industrial park. The Sustainability Roadmap is intended to provide a decision-making tool for assessing and benchmarking the KIA's sustainability achievements and to provide a map for guiding the KIA's future sustainability efforts. A matrix of different sustainability indicators will form the core of the Sustainability Roadmap and provide individual targeted performance metrics in managing sustainability performance over the longer term. The achievement of these indicator targets will go a long way in providing more sustainable performance outcomes for the KIA.

The aim of this paper is to open discourse on sustainability management in industrial parks, particularly Eco-industrial parks, and to review current and potential sustainability indicator systems for Eco-industrial parks that can measure sustainability performance. Using the KIA as a case study, this paper evaluates three important aspects of sustainability metric selection: the practicalities of sustainability indicator choice and interpretation, the challenges in selection and the lessons learnt during the selection process.

The first section of this paper reviews the concept of sustainable development in relation to an Eco-industrial park. The second section reviews recent literature on the use of sustainability indicator frameworks. The third section reviews the methodology utilised in developing the indicator matrix and the choice of metrics. The fourth section reviews the lessons learnt in the application of an indicator framework in an Eco-industrial park. The final section summarizes the research findings and discusses the implications for future sustainability indicator frameworks for industrial areas/Eco-industrial parks.

2. Sustainable production and development within multi-stakeholder, social-ecological systems: an industrial park perspective.

The concept of sustainable production emerged in 1992 at the United Nations Conference on Environment and Development (UNCED). Since then a number of sustainability and environmental performance indicator frameworks have been developed including the Global Reporting Initiative (GRI:a matrix of over 200 indicators), World Business Council for Sustainable Development Metrics (WBSCD:100 varied indicators) and the International Organisation for Standardisation (ISO: up to 300 different indicators in ISO14000).

Ranganathan (1998)defined a "sustainability indicator" as information used to measure and motivate progress towards sustainable goals and noted that the indicators chosen to represent these goals must be comparable, complete and credible in order to support the evolution of a standardised reporting structure.

Veleva and Ellenbecker (2001) also supported the growing need for standardised sustainability indicators to allow comparisons between companies, and suggested a simplified framework of 22 both quantitative and qualitative indicators as a step towards common measures for sustainability. They concluded that whilst the creation of a set of meaningful and simple indicators of sustainable production is very difficult, the exercise in indicator development alone heightens companies awareness of sustainable production, promotes organisational learning and improves measurement practices.

The standardisation of sustainability indicator frameworks therefore assists in the movement towards global sustainability performance metrics.

When developing sustainability indicator systems for a nation, region or an industrial area, it should be acknowledged however, that sustainability is not a fixed or static goal, but rather a 'common journey' as noted by the US National Research Council on Sustainable Development (NRC, 1999).This suggests that the pathways for transition towards sustainability cannot always be charted fully in advance given the intricate links within social-ecological systems like an industrial park (Anderies *et al*. 2004; Gallopin 2006).

It is also recognised that all social-ecological systems are complex and adaptive systems (Levin, 1998; Walker *et al*. 2004). Complex in that they are diverse and made up of multiple interdependent elements with feedback at many different levels and adaptive in that they have the capacity to self-organise, change in a dynamic and unpredictable manner and learn from experience (Gell-Mann, 1994; Holland, 1995). Changes in one domain of the system, social or ecological, inevitably affects other related domains. This has important implications for sustainability assessments, in that it is not possible to assess one domain without the other (Ramos andCaeiro2010).Similarly, the different 'pillars' of sustainability (economy, environment, society and more recently noted - time) cannot be studied or assessed in isolation from each other, since they are inherently interconnected across a full range of scales (from local to global).

Complex adaptive systems research therefore requires the development and application of research approaches that differ to a considerable degree from "*science as we know*" (Kates *et al.* p 641). They argue that *"a new field of sustainability science is emerging that seeks to understand the fundamental character of interactions between nature and society"*. This poses a challenge for sustainability assessments and the search for representative sustainability indicators. It requires the co-operation of scientists from disciplines as diverse as biology, geography, sociology, anthropology, economy, political sciences and engineering. It also calls for participatory research and planning approaches that are based on community and stakeholder engagement and social learning (Vernooy and McDougall, 2003; Blackstock *et al*. 2007; Johnston *et al*. 2004). Participatory research emphasises bottom-up approaches, focuses on locally defined priorities, and tries to capture and understand multiple perspectives (Pain, 2004). Participatory research differs from traditional 'expert research', that is designed and carried out by the researchers alone, as it aims to incorporate local knowledge by empowering knowledgeable 'non-experts' to participate actively in collective learning processes (Okali *et al.* 1994; Greenwood *et al*. 1993).

Furthermore it is clear that scientific exploration, and practical application must occur simultaneously, given their inter-dependence (Kates *et al*. 2001). Adaptive management approaches recognise the importance of examining the responses of ecosystems as people's behaviour in them changes (Holling, 1978; Walters, 1986) in order to learn something about society-nature interactions and the systems in play, and ultimately to seek to develop better policies and practices. The focus therefore should be on fostering continuous and collective learning processes amongst all stakeholders in the region.

It is important therefore to remember that within any Sustainability Roadmap and indicator development, developed targets and action planning around sustainability goals may need to be adapted continuously.

3. Sustainability performance measurement in industrial parks

There are a wide variety of potential applications for the development of sustainability indicators for the assessment of industrial parks and regional industrial areas.

The use of sustainability indicators importantly assists in the development of a new sustainability assessment approach that can be benchmarked internationally and can provide aspirational target setting, for example in a Sustainability Roadmap, for ongoing management and assist in the development of more targeted sustainability management systems.

Hezri (2004) argues for the adoption of 'policy orientation' as a framework to analyse and design macro-information systems that encourage sustainability outcomes and calls for the important development of links between sustainability indicators and policy approaches. For example, Van Gerven *et al*. (2007) in their review of sustainability management in the 'industry and energy' sectors in Flanders noted that when benchmarked with other industries across four sustainability indicators (eco-efficiency, environmental management systems, environmental expenditures and renewable energy), 'waste production' by industry was increasing at a rate higher than the benchmark production index suggesting a need for increased policy support in industrial waste management.

Valentin and Spangenberg (2000) view sustainability indicators as a 'compass' to help measure progress of plans or their implementation to achieve desired sustainability outcomes. They recommend broad and systematic participation of different societal groups during the development of sustainability indicators to help strengthen the local community contribution to sustainable development.

Ramos and Caeiro (2010)noted the role of academia and regional public authorities in working together with multi-stakeholders in the development of regional sustainability indicators. Using the example of the Algarve in Portugal, they showed how the development of regional sustainable development initiatives can encourage other regions to adopt similar practices, promoting benchmarking and collaborative sustainability initiatives.

Mattiussi and Rosano (2011) examined the possibility of developing a set of benchmark indicators to assess the environmental sustainability of industrial parks utilising four main environmental sustainability categories- air emissions, water emissions and waste management both in terms of the waste produced and potential waste by-product exchange (industrial symbiosis).They concluded that the development of industrial sustainability indicators for air releases, water discharges, waste management and waste/by-product/resource recovery is a positive step forward in both formally acknowledging the potential impact of the industrial park on the surrounding environment, but also in measuring the industrial symbiosis benefits and in benchmarking the capacity in industrial systems to improve their sustainability management practices to achieve both better efficiencies and less impact on the environment.

3.1 The challenges in developing meaningful and comprehensive indicators

It should be noted that sustainability indicators themselves are more than a summation of data or statistics. They are meant to provide meaning beyond the attributes directly associated with them and provide a bridge between detailed data and interpreted information. Sustainability indicators record and reflect values (UNSCD, 2001; Meadows, 1998), and in themselves are valuable tools to foster collective learning processes, particularly in areas like an industrial region facing community pressures.

Accepting the premise that sustainability is a problem arising from the interaction between society and nature means that sustainability indicators need to reflect more than just growth or environmental impact. They need to provide stakeholders with a basic understanding of how production (industrial) activity, the neighbouring communities and in particular local natural systems are interconnected, and may involve understanding questions like:

1. How does the activity of companies in the industrial region impact on neighbouring communities?
2. What impacts do socio-economic activities in the region have on the adjacent natural systems?
3. How do these changes affect local residents?
4. What are the main drivers for these changes and how can they be influenced by industry, local government and the local community?

In this paper it is argued that sustainability indicators can contribute to answering these questions if developed and utilised within a context of stakeholder engagement.

While the choice and use of sustainability indicators is of critical importance in providing useful support for sound decision-making processes (Meadows, 1998), it needs to be acknowledged that no set of indicators can be final or definitive (UNEEA, 1999). The search for sustainability indicators is an evolutionary process requiring both collective learning and adaptive management techniques in order to develop and select meaningful and comprehensive indicators.

One of the main questions that arise during an indicator selection process is that of the 'appropriate number of indicators'. Indicators are often intended to reflect a multiplicity of perspectives (UNEEA, 1999). The more diverse the stakeholder group, the longer the initial indicator list will need to be in order to capture this plurality. This question highlights the inherent challenges in the design of indicator systems, but also highlights the potential to stimulate collective learning processes amongst stakeholders, as these differing indicators can be used as a tool for expanding, correcting, and integrating worldviews.

Another frequently discussed issue in relation to indicator selection is that of measurability and objectivity. Most organisations emphasise the need to use 'measurable' indicators that are relatively easily obtained and can build upon existing data. In the scientific world, measurable quantitative indicators are viewed as objective and more reliable, as they can be validated by others and are more easily communicated. Qualitative indicators based on the perception of individuals are often classified as being subjective, as they cannot be transferred into generally accepted numerical references. However, it needs to be acknowledged that the choice of indicators itself will always be subjective as this choice is guided, as already discussed, by values and current knowledge; "*A choice to pay attention to what is measurable is in itself a subjective choice*" (Meadows, 1998, p9).In particular, aspects of quality of life, such as happiness, harmony, security, freedom, and well-being are qualities that are difficult to define and measure, no matter how relevant. Basing decisions on what is measurable only, will most certainly omit important aspects of sustainability. It is therefore argued that stakeholder engagement and participation during the indicator selection and planning process, will assist in bridging the gap between purely quantitative data and other more subjective but equally relevant information and therefore allow for better indicator selection and sustainability decision-making.

4. The Development of the Kwinana Sustainability Roadmap

4.1 The value of a Sustainability Roadmap

Western Australia is the largest and most sparsely populated state in Australia. The State has rich endowments of natural resources, including iron ore, bauxite, gold, nickel, mineral sands, diamonds, natural gas, oil, and coal. Heavy process industry is concentrated in a few industrial areas, of which the KIAis by far the largest and most diverse. The KIA was established in the 1950s following a special Act of Parliament, which secured an area of 120 square km's to accommodate the development of major resource processing industries in Western Australia. Kwinana is located 40 km south of the capital city of Perth on the shores of the Cockburn Sound, a sensitive marine environment (Figure 1).

Figure 1: Aerial view of the Kwinana Industrial Area (courtesy of the Kwinana Industries Council)

The KIA has well developed infrastructure, including a deep-water port, two power stations, water and waste water treatment plants and a good supply of skilled labour. The core industries in Kwinana employ about 4,800 people, and provide indirect employment to approximately 26,000 people. The combined annual output of the area is valued at A$15.77 billion per annum; in 2004/5 the industries reached direct sales of A$8.51 billion (SKM, 2007). Overall, the industrial region has long been recognised as a cornerstone of the Western Australian economy and plays an important role in the local community.

The KIA is currently facing sustainability challenges on a number of fronts including, increasing pressures on water and energy availability, climate change, an aging workforce, and growing community expectations for improved sustainability management. These challenges are primarily addressed through the Kwinana Industries Council (KIC), which was established by the core industries in the KIA in 1991 as the region's first formal industry association. The KIC is now an incorporated business association with membership drawn from all the major industries and many of the smaller businesses in the KIA (KIC, 2009). The original purpose of the Council was to provide the required regulatory air and water monitoring for the KIA. This was in response to increased government and community pressure to manage its air and watersheds, and protect the sensitive marine environment in the adjacent Cockburn Sound. The KIC now addresses a broad range of environmental issues common to Kwinana's major industries, such as air and water quality, cumulative noise and vibration, contaminated sites, waste management, visual amenity and transport and infrastructure related issues. Towards this end, the Council collaborates closely with government authorities and other relevant stakeholders to develop best practice guidelines that assist members in reducing their environmental impact. The KIC also seeks to foster positive interactions between member companies, government, and the broader community. Meaningful stakeholder engagement is a high priority for the KIC with a constant focus on building enduring relationships with neighbours, research institutions and community groups that are based on mutual respect, long-term commitment and shared understanding (KIC, 2009).

Over the past decade, significant progress has been made by KIA industries toward the improvement of their sustainability performance at both company and regional level. Given increasing sustainability pressures, there is a strong desire to address sustainability challenges in the KIA, through a pro-active and collaborative industry approach. Since April 2004 the Sustainable Engineering Group at Curtin University (previously the Centre of Excellence in Cleaner Production)have been assisting the KIC and its members in their movement towards improved sustainability performance management through the development of a Sustainability Roadmap with relevant performance indicators (CSRP, 2008).

In the last two decades substantial research efforts have been made in developing sustainability indicator frameworks and methodologies at national and international levels to improve comparability, significance and efficiency of sustainability assessments (UNSCD, 2001; OECD,2003). Most frameworks provide valuable guidance on the choice of indicator themes and indicator measures.

The sustainability reporting framework of the Global Reporting Initiative (GRI) is the world's most widely used framework for reporting on an organisation's economic, environmental, and social performance (GRI, 2002). The GRI framework is based on a list of performance indicators, which have been identified for a number of generally applicable key themes: economic, environmental, labour practices and decent work, human rights, society, and product responsibility. Various sub-themes, called 'aspects' contain core and additional indicators. Whilst the GRI framework has been designed for individual companies/organisations, rather than for entire industrial areas, it is suggested in this paper that it could be used as a starting point and for guidance throughout the indicator selection process.

4.2 Choosing suitable sustainability indicators- the Kwinana experience.

In early 2009, the KIC, through its Eco-efficiency Committee agreed on the development of a Sustainability Roadmap to provide a longer term strategy for sustainability management in the KIA. This roadmap was to be based on the further development of the a Sustainability Matrix Framework utilising a number of key sustainability focus areas that would be then populated with relevant sustainability indicators to reflect both the desired sustainability performance of the KIA and to act as a tool for international benchmarking and comparative assessment. After early 'industry only' indicator discussion and selection, it soon became apparent to the KIC that the local community needed to be involved in the sustainability indicators selection process, if the Sustainability Roadmap was going to achieve desired community sustainability outcomes. As a result in February 2009, the KIC developed an Environmental Improvement Strategy (EIS) supported by external stakeholder engagement to select the sustainability performance indicators for the Sustainability Roadmap.

Three EIS 'sustainability indicators selection' workshops were held in March, May and June 2009 at the KIC with over 20 industry, government and community representatives. These workshops were facilitated by an independent moderator and included senior management from the KIC. In these workshops an open table discussion initiated ideas on early sustainability indicator selection, which were then refined and summarised over the three workshops. Seven key 'focus' indicators were chosen for the Sustainability Management Matrix together with supporting primary and secondary performance indicators to serve as 'aspirational targets'.

The seven focus indicators chosen were: energy, water, by-products, economy, ecological health, community and workforce.

An important selection criterion for the performance indicators was that the KIC and industry members should be able to influence their selection, and that they could provide a basis for comparing the performance of the KIA with other (inter)national industrial areas (van Beers, 2008).

Similarly, Warhust (2002) advocated '*tailor made'* indicator sets, which address specific stakeholder concerns whilst supporting the organisations' operational strategies. Such an approach is suggested to more effectively assist stakeholders in the achievement of their sustainability goals than approaches which prioritise reporting against generic '*off the shelf*' indicators. Notwithstanding this, it is also suggested that the latter can inform the former, and that there are merits in developing combined *'top-down'*, *'expert derived'* and *'bottom up'*, *'stakeholder scoped'* approaches within sustainability performance assessment and management.

4.3 A framework for sustainability indicator selection- a Sustainability Management Matrix

This initial list of seven focus indicators noted above was discussed with all three stakeholder groups (KIC, Industry members of the KIA and the Kwinana Community group) during three separate workshops and generated a preliminary set of primary and secondary performance indicators. This framework was then called the KIC Sustainability Management Matrix (Table 1). The seven focus indicator categories are noted under 'Outcome sought'.

Table 1: KIA Sustainability Management Matrix

	Primary Performance Indicators		Secondary Performance Indicators	
Outcome Sought	**Name**	**Unit**	**Name**	**Unit**
Carbon neutral KIA **(ENERGY)**	Net GHG emissions (CO_2-e) per economic output	ktonnes CO_2-e / $Bn KIA GDP	CO_2 emissions	kt CO_2
			GHG emissions	kt CO_2–e
			GHG emissions offset	kt CO_2-e
World benchmark in energy conservation **(ENERGY)**	Total energy consumption per economic output	PJ/$Bn KIA GDP	Total energy use	PJ
			Utility synergies (energy)	TJ
Zero process use scheme water **(WATER)**	Total water use per economic output	%	Total water use	GL
			Ground water use	GL
			Surface water (total)	GL

Outcome Sought	Primary Performance Indicators		Secondary Performance Indicators	
	Name	Unit	Name	Unit
World benchmark in water conservation **(WATER)**	Fraction scheme water in total water use	GL /$Bn KIA GDP	Surface water (low quality)	GL
	Fraction of recycled water in total water use	%	Scheme water use	GL
			Off-site water recycling (synergies)	GL
World benchmark in reused by-products **(BY-PRODUCTS)**	Reused by-products as fraction of total process residues	%	Process residues	kt
	Number of by-product synergies	-	Re-used by-products	kt
Recognised as the premier industrial estate in Australia **(ECONOMY)**	Contribution KIA GDP to WA GSP	%	Total sales (KIA GDP contribution)	$M
			Direct and indirect wages and salaries	$M
			Purchase of goods	$M
			Purchase of imported goods (international and national)	$M
			Total number of material interactions	-
World benchmark on industrial emissions **(ECOLOGICAL HEALTH)**	Air emissions per economic output ▪ SO_2 ▪ NOx ▪ PM10	tonnes / $Bn KIA GDP	Air emissions ▪ SO_2 ▪ NOx ▪ PM10	tonnes
	Cockburn Sound quality measures ▪ Physical/chemical ▪ Direct biological ▪ Toxicants	Below guidelines in selected criteria	-	-
	Number of incidents of non-compliance with noise regulations in KIA	-		
Welcome neighbour **(COMMUNITY)**	Contributions to community program per economic output	$k / $Bn KIA GDP	Contributions to community programs	k$
	Fraction community that believes industry has positive impact on community wellbeing	%		
Sustainable workforce **(WORKFORCE)**	Number of direct and indirect employees per economic output	employees / $Bn KIA GDP	Employees	Direct (indirect)
	Fraction apprentice / traineeships of total direct workforce	%	Apprentice / traineeships	Total (female)
	Fraction employees living locally	%	Fraction females in workforce (fulltime)	%
	Lost Time Injury Frequency Rate (LTIFR)	No of lost time injuries per million hours worked	Employees > age 55 years	%
			Total lost time injury	days per year

Whilst the seven different focus areas were chosen to reflect the major sustainability and environmental pressures facing the KIA, the Sustainability Management Matrix was developed as the framework around which the potential primary and secondary performance indicators could be chosen as indicators of both sustainability performance measurement and outcomes sought as aspirational targets by the Sustainability Roadmap.

All KIA stakeholders in the workshops agreed that the selection of their individual sustainability performance indicators within a Sustainability Management Matrix should be focused on a small number of key indicators, but still be large enough to provide a holistic overview of the sustainability performance of the KIA. The matrix noted in Table 1. contains 17 primary performance indicators and 25 secondary performance indicators. This was perceived as a manageable number but still useful and relevant for external reporting and internal communications.

All seven focus areas were selected as representing major environmental and sustainability challenges both for the KIA and Australia wide. The 'water' focus indicator in particular created a significant level of discussion during the workshop and for the purposes of this paper is discussed separately in the next section in order to illustrate the importance of participatory research methods in the sustainability indicator selection process.

4.4 Key focus indicator selection- a case study

Increasing water demand in Western Australia is currently a significant community issue with the demand pressures from increasing population growth, intensive agricultural development, urbanisation, and industrial expansion. This growth of water demand is further challenged by declining rainfall levels in south-west Western Australia (Young *et al, 2006).* Water runoff into dams has declined in Western Australia by some 40-50%since 1975 with decreased rainfall and climatic change. As a result the Western Australian State Water Strategy includes a water reuse target of 20% by 2012 (GoWA, 2003).

Over the past 10 years significant progress has been made towards the improvement of water consumption and waste water disposal in Kwinana, both at company level (e.g. on-site water efficiency assessments at various KIC member companies) and at a regional level through the industrial symbiosis program which has assisted in the identification and implementation of additional water reuse and recycling options (van Beers, 2008). The West Australian State Government is increasingly requiring major water users to demonstrate responsible use of water by setting up and implementing water efficiency management plans (Water Corporation, 2007). During the sustainability indicator selection workshops the KIC and the majority of participants all recognised an urgent need to further investigate the opportunities for enhancement of water efficiency and reduced effluent disposal given declining water supplies, rising water prices, increasing external pressures from government and other stakeholders, and anticipated expansion plans for the KIA.

As a result, Table 2 shows the primary and secondary performance indicators chosen for water as a key focus (sustainability)indicator.

Table 2: Targets and performance indicators for the water 'focus indicator' (Financial year 2009/10)

Water 'focus indicator'				
Aspirational Targets	**Primary Performance Indicators**		**Secondary Performance Indicators**	
Zero process use scheme water	Fraction scheme in total water use	14.7 %	Scheme water use	4.9 GL
			Ground water use	16.7 GL
World benchmark in water consumption and recycling	Total water use per economic output	2.1 GL/$Bn KIA GDP	Surface water	3.1 GL
	Fraction off-site water recycling in total water use	24.5 %	Off-site water recycling	8.0 GL
			Total water use	32.7 GL

The aspirational goals chosen for this focus indicator were to reduce the use of scheme water for industrial processes to zero and for the KIA to become a world leader in industrial water efficiency. Currently 14.7% of the total water used in the KIA is scheme water, while 24.5% is recycled water from secondary treated effluents. A high percentage of the recycled water is produced by the Kwinana Water Reclamation Plant (KWRP), which is a joint initiative of the state Water Corporation and Kwinana industries and became operational in late 2004. Whilst the industry participants were primarily focussed on the efficiency gains associated with recycled water use, community participants were more concerned with the water quality of watersheds to the local marine environment. The dual purpose inherent within the sustainability impact of the water focus indicator in terms of 'efficiency' versus 'water quality' highlighted a significant benefit in the prioritisation of the indicators as well as in the ability of an indicator to reflect both better efficiencies as well as less impact on the environment.

The KWRP treats about 24 ML/day of secondary treated wastewater from the nearby Woodman Point wastewater treatment facility in a micro filtration/reverse osmosis unit to produce a high quality industrial grade water stream. It is the biggest water recycling plant of its type in Australia. Approximately 17 ML/day of recycled water is supplied to large Kwinana industrial sites including CSBP, Tiwest, Kwinana Cogeneration Plant, BP and HIsmelt. This recycled water helps to replace scheme water(6 GL/year)used by the KIA, which previously accounted for around 2-3% of the annual scheme water use in the Perth metropolitan area (Water Corporation, 2003).

In addition, other measures to reuse recycled effluent as process water have been implemented at Alcoa's alumina refinery. Treated wastewater from the Kwinana wastewater treatment plant is infiltrated into groundwater upstream of the Alcoa groundwater extraction bores. The bores supply about 1 GL/year of process water for the refinery (van Beers, 2008).

As a result of the Sustainability Management Matrix, the KIA is now setting five year goals across the seven focus indicators(e.g. for the water indicator increasing the proportion of off-site recycled water by an additional 20% by 2012) and will decide on appropriate strategies and initiatives to achieve these individual goals. Another specific strategy for the water focus indicator will be the extension of the KWRP, which is currently in the design stage. Specific initiatives already undertaken by the KIC include various workshops and water scoping studies (CSRP, 2008)and a comprehensive Water Planning Study of the KIA (KIC, 2006). As a result of the importance of the water focus indicator in the Sustainability Management Matrix, two additional research projects were initiated by the KIA in order to explore potential effluent synergies. The first project is to review the possibilities of using waste heat from Kwinana flue gases to power a new desalination plant and the second project reviews the possibility of using industrial effluents in evaporative water desalination systems (CSRP, 2009).As a result, the enhanced participatory research process in this case study also has provided further strategic direction for the KIA in its management planning of this key indicator.

4.5 Sustainability Indicator inter-connectivity

It should be noted that the water focus area is also interconnected with other focus areas in the KIA Sustainability Management Matrix, including in particular economic performance, and community and ecological health. Water reuse and recycling in the KIA will benefit neighbouring communities and Perth overall by making more scheme water available for household use. Industries using the high quality recycled water from KWRP are furthermore able to reduce the use of water chemicals in cooling towers and other process applications, thereby reducing chemical discharge to the marine environment (Water Corporation, 2003).In exchange for taking water from the KWRP, the industries are able to discharge their treated effluents into the Sepia Depression Ocean Outlet Landline (SDOOL) which will reduce their water discharges into the adjacent Cockburn Sound. The SDOOL, which has been operating since 1984, discharges municipal and industrial treated effluents approximately four kilometres offshore. The Water Corporation now monitors the environmental impacts of the SDOOL water through the Perth's Long-term Ocean Outfall Monitoring (PLOOM) program in order ensure that harmful effects on the adjacent reefs and the beaches are avoided (Water Corporation, 2003).

For this reason the KIC is an active participant in the Cockburn Sound Management Council (CSMC), along with State and local governments and a range of community groups. A key role of the CSMC is to undertake community consultation regarding issues and activities concerning the Sound and region (KIC, 2004). The Sustainability Roadmap for the KIA therefore became a basis for stakeholder discussions on sustainable development strategies for the region within forums such as the CSMC.

4.6 The benefits of a Sustainability Roadmap

Important sustainability management challenges, like for example, collective water use, are beyond the scope of individual businesses or annual sustainability management plans. For example, whilst the effluent emissions of one company in an industrial region might not have any adverse impacts on the adjacent ecosystems and/or communities, the cumulative impacts of all companies will eventually reach important thresholds and can result in irreversible adverse effects. Conversely, the efforts of one company in reducing their emissions might not allow the social-ecological systems to stabilise. A Sustainability Roadmap for the KIA therefore plays an important role in creating a shared vision and a common direction in the region, based on aspirational targets and underpinned by specific goals and initiatives on a ' common journey towards sustainability'.

The Sustainability Management Matrix presented in this paper, will continue to be further developed by the KIC utilising the external stakeholder participatory approach. This will include the collection of historical industry data to quantify selected sustainability indicators (historical trend analysis) and the documentation of Kwinana case-studies for the potential development of international benchmarks for industrial park sustainability performance measurement.

The Sustainability Management Matrix has assisted the KIC in the early development of its first Sustainability Roadmap to assist as a decision making tool in the long-term sustainability management of the KIA. As a first step, a construct for a KIA Sustainability Roadmap was developed (Figure 2), using the Sustainability Management Matrix and the chosen primary and secondary performance indicators. These indicators represent the aspirational 'outcomes sought' in the workshops and were seen to be critical to the long term sustainability performance of the KIA.

Figure 2: KIA Sustainability Roadmap

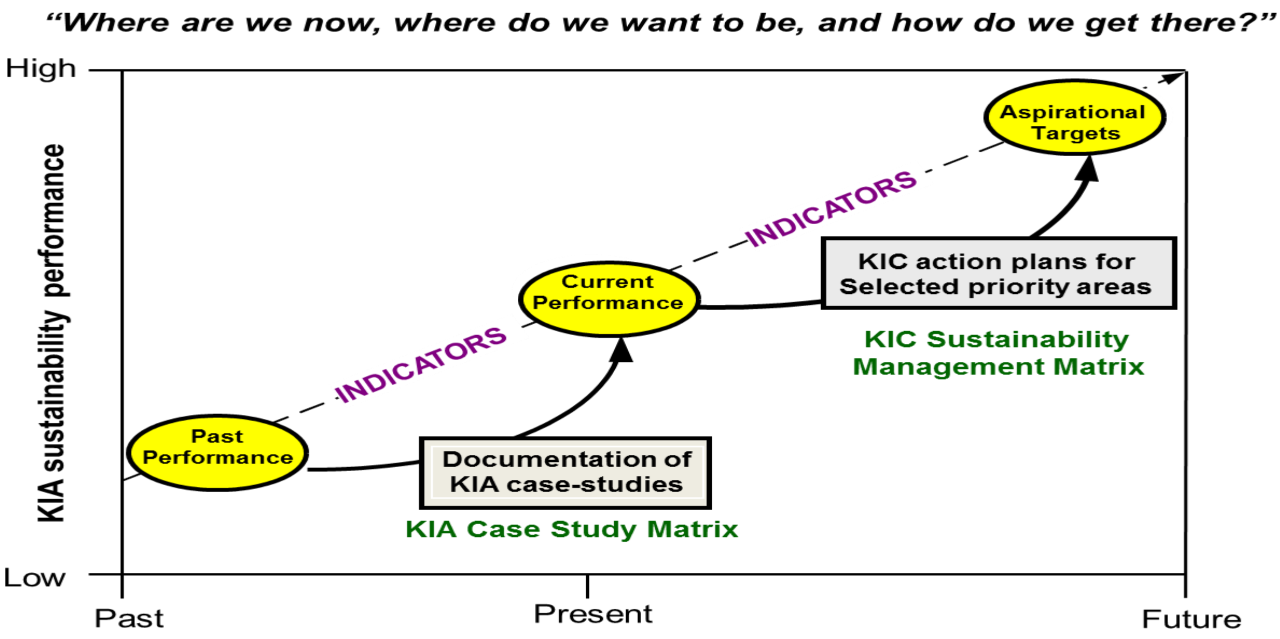

Figure 2 illustrates how sustainability indicators can be used to both measure past and current performance of the KIA and set aspirational sustainability management targets. The purpose of the KIA Sustainability Roadmap is to provide a construct around which action plans for selected sustainability priority areas can help achieve long term sustainability performance goals and outcomes ("what the future could look like and how do we get there"). Whilst the KIA Sustainability Roadmap is still undergoing further development the Sustainability management Matrix highlights the potential for including sustainability related indicators that reflect the major sustainability and environmental concerns of both industry and its local community.

The next steps include the setting of five year aspirational targets and specific volume/value goals for each indicator and formulating subsequent strategies and action plans to meet these targets. The focus will continue to be on activities where the KIC has an influence and can make a positive impact. In its final form the KIA Sustainability Roadmap will enable ongoing constructive stakeholder discussions (e.g. government and community) on emerging local issues and possible future directions for the KIA.

5. Lessons learnt

The KIA Sustainability Management Matrix is one of the first documented formal sustainability indicators frameworks developed across an entire industrial estate to assist with industrial sustainability road mapping. The researchers involved focussed on indicator data that were reflective of the main sustainability issues faced by the industrial area, were available, measurable and could allow for objective comparison and also allowed consistent and transparent methods of data collection and management.

A number of lessons have been learnt in the development of the Sustainability Management Matrix that are worthy of further discussion in relation to future industrial sustainability road mapping efforts.

Firstly, one of the major difficulties faced was in obtaining the required data to set up the matrix to allow meaningful interpretation of historical trends associated with the indicators. Initially the KIA wanted to limit the number of indicators being sought to reduce the need for onerous data reporting requirements from the companies involved. Proxy data were also considered but were often seen to be a poor substitute for actual indicator data. The project acknowledges that a continuing centralised effort is required to collect and accumulate further data if the matrix is to provide the desired sustainability impact assessment. Spread sheet tools were developed to assist the data management and to allow simplified monitoring of trends and reporting of the indicators.

Secondly, mid-way through the project the development of the performance indicators raised the question of the need for broad stakeholder engagement in the selection and endorsement of the indicators. As a result it was decided to develop an Environmental Improvement Strategy (EIS) supported by external stakeholder engagement that would select the performance indicators to be reported. The development of the EIS was then given priority. On reflection it was agreed that the initial project plan was 'back to front' in its initial selection of the indicators and subsequent stakeholder approval. The development of the EIS will allow the external stakeholders to provide input into aspects they consider important and this will then provide additional guidance to the selection of the key indicators for a Sustainability Roadmap. This way, the development of key indicators will gain a much broader acceptance than if they were to be developed by industry and then presented to broader stakeholder groups for comment as was initially planned.

This additional process has highlighted the importance of validating the key areas for the KIC to focus its Sustainability Roadmap on, and has importantly –and by default-confirmed additional areas requiring sustainability management/input by the KIC (ie: use of low quality water, use of waste heat, facilitation of by-product utilisation through regulatory and policy change) in achieving longer term enhanced sustainability management.

6. Conclusions

The development of the KIA Sustainability Roadmap is an iterative process based on participatory research approaches and stakeholder engagement, with the additional aim to foster continuous collective learning towards enhancing sustainability performance management. This paper supports the collective learning process, starting with the discussion of sustainability concepts and the selection of suitable sustainability indicators by relevant stakeholders, which in turn should reveal the differing values and attitudes of the stakeholders, and ultimately help in reconciling these differences. The research furthermore demonstrates the interconnectedness of social, economic and environmental aspects of sustainability, and evaluates how this is reflected in the interrelations between indicator focus areas and indicator measures. It is suggested therefore that it is not possible to assess changes in indicator measures in isolation from each other.

In order to be useful as a strategic decision-making tool, the KIA Sustainability Management Matrix has to be easy to understand and useful for benchmarking and comparative purposes. In addition, it needs to be able to support local environmental protection and management authorities within the framework of an adaptive management approach. Sustainability research efforts have to cover many different discipline areas including biology, geology, engineering, cleaner production, social sciences, and complex systems theory. The Sustainability Management Matrix developed by the KIA brought together different research groups, stakeholders from government and community that integrated both expert research and local 'non-expert' knowledge to enable ongoing constructive discussions on emerging sustainability issues and possible future directions for the KIA.

Large industrial parks like the KIA face continuing pressure in securing their 'social licence' to operate. Industry is recognising it must respond to these challenges by engaging many different stakeholders and directly addressing their sustainability concerns. Furthermore, industry must also be able to measure and assess their sustainability performance for these stakeholders and demonstrate continuous improvement over the longer term. A Sustainability Roadmap, engaging stakeholders in its development, should help to achieve both these outcomes.

More work is needed in further developing the KIA Sustainability Management Matrix and its preparation for presentation in both public annual reporting documents and as a strategic decision making tool and its use as a performance measurement tool in a Sustainability Roadmap, but the lessons learnt during its early development, highlight the challenges faced in translating sustainability issues into indicators of sustainable development and the importance of developing the roadmap together with the stakeholders sharing the journey.

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