A Review of International Low Carbon Precincts to Identify Pathways for Mainstreaming Sustainable Urbanism in Australia.

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Abstract

Urban environments, once built, are slow to change, therefore the neighbourhoods we build today, will ideally be designed to meet our future needs. The combined challenges of climate change, population growth and finite resources demand we rapidly decarbonise our cities. Failing to provide the necessary infrastructure to decarbonise Australian cities today will place a social, environmental and economic burden upon future generations of Australian society.

At a high strategic level this imperative is acknowledged but in practice government planning agencies have typically placed greater emphasis upon maintaining land supply and housing affordability over effectively fostering a culture of sustainable urbanism. The absence of a strong sustainability culture within the built environment sector, has seen barriers, such as the 'sustainability cost premium' and the political 'short termism' of a three year electoral cycle, impede more rapid transition to a widespread culture of sustainable urbanism practice.

This paper describes six international 'low carbon precinct' case studies to show how they were able to overcome some of these barriers. The case studies employ a diverse range of strategies including demonstration project trials, integrated eco-services, and innovative funding models to deliver low carbon precincts. It shows how political, skill and market barriers can be overcome through the use of different delivery models, and how these models may provide useful lessons to help develop pathways to decarbonise urban development in Australian cities.

Introduction

Urban environments, once built, are slow to change, therefore the neighbourhoods we build today, ideally, need to meet the social, environmental and economic needs of the future. The combined challenges of climate change, population growth and finite resources demand decarbonising our cities. Failing to provide the necessary infrastructure to decarbonise Australian cities today will place a social, environmental and economic burden upon future generations of Australian society.

This paper discusses common barriers to sustainable urbanism, including lack of skilled labour to deliver sustainable projects, the 'sustainability cost premium' and the 'short termism' of a three year political electoral cycle. These barriers have been overcome by a number of international 'low carbon precincts' presented here as six case studies.

This paper focuses on precinct scale development as precincts may provide the best opportunity for incrementally decarbonising Australian cities during the transition from unsustainable conventional practice to widespread sustainable urbanism. Precinct scale initiatives can help trial and test subdivision/neighbourhood wide urban eco-services that would not be possible at the individual building scale. Low carbon precincts are the ideal places to trial innovative processes and technologies that can inform urban policies or institutionalised financial incentives to ultimately mainstream the type of sustainable urbanism needed to decarbonise Australian cities.

Approach

A range of low carbon exemplars were identified through a literature review and six were selected for inclusion in this paper where they were able to demonstrate innovative delivery mechanisms that allowed one or more of the sustainable urbanism barriers (as described in detail below) to be overcome.

The low carbon precincts presented are BedZED (UK), One Brighton (UK), Peterborough Carbon Challenge (UK), Hammarby Sjostad (Sweden), Vauban (Germany) and the City of Berkley PACE scheme (USA). These case studies are all proven exemplars of sustainable urbanism and demonstrate a diverse range of strategies including demonstration project trials, integrated eco-services, and innovative funding models to deliver low carbon precincts. The paper discusses the key sustainability initiatives associated with each project and the processes used by stakeholders to deliver them. A range of 'lessons' are outlined in the concluding section to offer a possible processes that may assist in 'mainstreaming' low carbon precincts in an Australian context.

Understanding the problem

Australia's greenhouse gas emissions

Per capita Australia produces more carbon pollution than any other developed nation. The building sector is a major contributor to Australia's greenhouse gas emissions with residential energy use alone accounting for around 12% of carbon dioxide (CO_2) emissions (Australian Government, 2013a). Australia's international commitment to an 80% CO_2 emission level reduction (below 2000) by 2050 is ambitious (Australian Government, Department for Climate Change). In response to this target, Climateworks Australia (2013) recommend that a low emissions built environment is a key goal for success (Denis et al. 2013). But achieving this target will require a radical shift in the building sector away from business as usual towards mainstreaming sustainable urbanism practice. The logistics of the challenge are likely to be exacerbated as a result of high population growth which is projected to be around 50-100% (30-42 million people) by the mid 2050s (ABS, 2008) this growth will make per capita emission targets even more onerous to meet.

The knowledge to deliver low emission built environments exists, but the challenge will be to find market-acceptable, cost-effective models for implementation. At present major structural and financial barriers are impeding the rapid transition from business as usual towards a sustainable urbanism.

Barriers to delivery of sustainable urbanism

Barriers to sustainable urbanism mainly relate to the inherent inertia of the high cost, risk adverse construction, engineering and development sectors. The irony is that while long term economics necessitate a transition to sustainable urbanism, short term economics are inhibiting change (Generation, 2012; Cole, 2012). Our urban fabric is currently being delivered through systems that have well established supply chains that are geared toward lower construction cost with little sustainability consideration. More sustainable options (that may prove cheaper over the product life cycle) are uncommon due to the additional cost and risk associated with sustainability innovation, in addition current regulations do not necessarily support the delivery of sustainable urban form and in many instances may even prohibit delivery (Newman, Bachels and Scheurer, 2010).

Our ability to shift towards low carbon, sustainable cities and lifestyles requires a sustainable (sub)urban infrastructure capable of maintaining liveability standards while helping minimise difficulties/resistance during a transitioning toward resource consumption reduction (Newton, 2012). The challenge will be to overcome the existing skills, political/policy and market barriers.

Skills Barrier – knowledge and workforce

Shifting from business as usual will require retraining of the work force at all stages of development delivery including design, planning and construction as well as streamlining material supply chains and services to facilitate sustainable outcomes. The skills to deliver sustainable

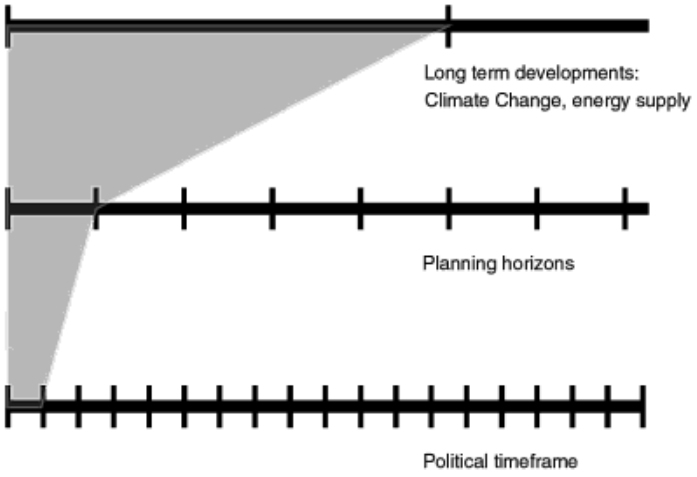
communities exist but 'best practice' is not the norm. Initiatives in Australia such as the Council of Australian Government (COAG) endorsed Green Skills Agreement aim to address this issue and state that, '*existing jobs will need to be redesigned through upskilling or re-skilling, to meet the skills needs of individual firms and entire industries in the move towards a more sustainable future'* (COAG, 2009).

In the European Union (EU), where some of the most stringent sustainable building requirements exist, the shortfall in sustainable building skills as a barrier to green building uptake is well documented. The EU International Labour Office suggest that the major gaps in the EU construction sector included poor quality installation and health and safety issues (International Labour Organization, 2011). Similar skills gaps could be expected in Australia. For example, the ambitious but ultimately flawed, Australian Government sponsored Home Insulation Programme that commenced in July 2009 before being ungraciously cancelled in February 2010 following much negative publicity. The Programme provided subsidies for building insulation and was touted to reduce household energy bills by 40%, but a skills deficient caused issues which according to *The Australian* newspaper 'has been linked to four deaths of installers, 120 house fires and up to 1000 electrified roofs' (Kelly, 2010). This example demonstrates that good programmes poorly executed due to a skill gap can result in failure.

Political Barrier – the short termism of a three year electoral cycle

The challenge that short term electoral cycles place upon the creation of meaningful climate change policy relates to the different time scale and the opportunistic nature of populist politics as Figure 1 illustrates (Roggema, 2012).

Figure 1: The different timeframes of politics, planning and climate change.
Source: 'Connection of long and short term' Roggema and Van den Dobbelsteen, 2008, cited in Roggema 2012



The visionary long term leadership required for sustainable development policy can be difficult because politicians are inherently reluctant to commit to policies that have no simple solution, no clear end point, that are likely to cost a lot with few short term benefits and that (most significantly) will not show clear results until well after the proponent's political career has ended (Roggema, 2012). Policy to support a sustainable low carbon future will remain sluggish while it is impeded by 'political party rivalry' and 'the politics of fear' (Carter, Pisaniello and Burritt, 2010) as witnessed in the political controversy and ongoing tussle around the *Clean Energy Act* (2011) (referred to as the 'Carbon tax') in Australia. Until issues such as climate change have stronger political consensus in Australia there will be a need for strong leadership from within industry and

the community to ensure the built environment sector keeps pace with longer term scientific and policy targets.

Market Barrier - the 'sustainability cost premium' in Australia

Industry leadership to deliver 'best practice' sustainable urbanism requires developers to deviate from conventional practice, often resulting in additional risk associated with innovation or new technology, this risk usually translates into a financial disincentive, the so-called 'sustainability cost premium' (Sustainability Victoria, 2011). Without a sponsor willing to pay a premium above market value to subsidise costs, the sustainability cost premium impedes sustainable urbanism. Most of the sustainable low carbon precinct case studies discussed in the next section of this paper have a sponsor (often government) willing to offer financial support to absorb risk and encourage a demonstration project. Subsidised demonstration projects, while performing a useful educational and marketing role, typically result in 'flagship' developments that represent an exception to the rule rather than common practice. Newton suggests that we need to move beyond this toward low-cost,

> *eco-efficient urban infrastructure, that is, infrastructure capable of delivering key services such as water, energy, housing, and mobility with reduced EFs* (ecological footprints) (Newton 2012, p.9).

Achieving this requires overcoming the market barriers associated with additional costs. These market barriers are further compounded by the well established notion of 'split incentives' whereby those making the capital investment decisions (the developer or landlord) are not the same entity as those responsible for paying energy bills (the property purchaser or tenant) (Australian Government, 2013b). Mainstreaming sustainable urbanism will only occur if market barriers and split incentives can be overcome, this paper identifies some novel ways in which this has been achieved in a number of case studies.

Case Studies

Effective pathways for delivery must overcome the combined skills, policy and market barriers if sustainable urbanism is to be mainstreamed. One way sustainable urbanism may be delivered is through a piecemeal approach of semi-autonomous precincts that incrementally deliver a more sustainable city. Six low carbon case studies are discussed, they all result from comprehensive development approach at the subdivision/precinct scale or local government sustainability initiatives. Table 1 provides a brief overview of the six case studies.

Table 1: Case Study overview

PROJECT	COUNTRY	DELIVERY MECHANISM	DESCRIPTION	PREVIOUS SITE CONDITION
BedZED	UK	Public private partnership	1.6ha Residential mixed use, 82 dwellings	Greenfield site (council owned)
One Brighton	UK	Market driven, developer initiative	Residential Mixed use with supermarket, 172 dwellings	Greyfield site (former surface car park)
Peterborough Carbon Challenge	UK	Public private partnership (government led and heavily subsidised)	Residential mixed use, 7ha 285 dwellings	Brownfield site (former industrial land)
Vauban, Freiburg	Germany	Market driven, community led	Urban neighbourhood 5000 residents + 600 jobs	Brownfield and greenfield site (former army barracks)
Hammarby Sjostad	Sweden	Public private partnership, government led	11,000 residential units for just over 25,000 people and a total of	Brownfield site (former naval yard)

			about 35,000 people will live and work in the area by 2015	
City of Berkley	USA	Property Assessed Clean Energy (PACE)	Voluntary clean energy financing incentive for local residents	Greyfield (City policy for retrofitting existing buildings)

BedZED, UK

Beddington Zero Energy Development (BedZED) is a suburban, mixed-use development of 82 dwellings and 2500m^2 of commercial or live/work space in South London; completed in 2002 this important low carbon precinct pioneer is now a mature low carbon development providing many lessons, particularly around overcoming skill barriers but also market barriers.

In 1997 the UK charity BioRegional, seeking new office space to house their growing environmental social enterprise, decided that instead of renting a conventional commercial space they would 'express their commitment and ideas by building a green office' (Desai, 2010). This resulted in the BedZED development.

BedZED was developed using a strong sustainability vision referred to as the 'One Planet Living Principles' (developed collaboratively by BioRegional and the World Wildlife Fund). These principles have since been promoted and adopted as a benchmark for other 'One Planet' sustainable developments. The ten principles relate to carbon, waste, transport, materials, food, water, biodiversity, culture, economy and happiness, and effectively function as a reference point for decision making throughout the development process.

The BedZED 'urban eco-village' includes a low energy, medium density urban development (approximately 50 dw/ha) on a subdivision oriented to maximise passive solar design . The super insulated buildings resulted in a 75% improvement upon UK building regulations (Desai, 2010, p.33), while renewable energy production in the form of PVs and biomass fueled trigeneration (supplemented by natural gas) resulted in an average 45% reduction in energy consumption (and 81% heating reduction) when compared to neighbouring, conventional developments. The development also included other innovations such as green roofs (accessible as private open space), rainwater harvesting, on-site 'enhanced reed bed system' for sewerage treatment and approximately 15% of total building material was derived from reclaimed or recycled sources (Desai, 2010).

Although the project was not a success financially, BioRegional cite two primary factors that helped off-set the 'sustainability cost premium'. These factors were the use of a 'planning gain mechanism' and the property value premium the green designs attracted.The planning gain mechanism involved trading green innovation for additional development area, in this instance the production of a 'green transport plan' allowed the developer to seek permission for a reduction in car parking provision and road space which was transferred to additional development space that in turn translated to additional returns (estimated to be in the region of £3.7 million additional development value) (BioRegional, 2009). The market appeal of the innovative product "*achieved premium values some 17-20% above the conventional new homes in the area. Buyers paid extra for the innovative design and the "green" credentials"* (BioRegional, 2009, p.8).

Having a strong environmental vision at the outset of the project and a steward or 'sustainability integrator' (Desai, 2010) ensured the sustainability vision (One Planet Principles) were not compromised at any stage of the process from concept, through detailed design, construction and post occupancy management.

Based upon their BedZED experience, BioRegional have partnered with, or acted as consultants for, developers on additional low carbon sustainable projects including One Planet Brighton, discussed next, to help disseminate their knowledge and increase the skills base for delivery of low carbon communities.

One Brighton, UK

One Brighton is a 172 unit, commercially viable follow-up to BedZED completed in 2010. It applies the One Planet Principles to a high density inner city development adjacent the Brighton Train Station. One Planet Brighton is a high density, mixed-use infill development built on a former surface car park in the city of Brighton on England's South Coast. The development includes a major commitment to social housing (30%) operated by an external housing association. The market driven development by BioRegional Quintain was a joint venture with builder partners Crest Nicholson (Desai, 2010).

The vacant site was initially bought by a supermarket chain to be developed as a typical 'big-box' supermarket with surface car parking, however community opposition to the proposal led to the local government requiring a comprehensive Master Plan that sought to incorporate the supermarket as one component of a mixed-use development that incorporated residential, retail and community space.

The purpose was to demonstrate that sustainable urbanism could overcome typical market barriers to be commercially viable and compete with conventional, unsustainable development.

The sustainability narrative did not dominate the sales pitch instead a 21st century lifestyle was pitched along with the idea of 'five minute living' – having shops, work, school, theatres and public transport all within five minutes of home. These collective messages allowed this development to outperform the major UK house builders sales rates in a difficult post Global Financial Crisis economy (50% improvement on industry benchmarks) (Desai, 2010).

The development sought very few concessions with the exception that negotiations were made with the council to reduce private vehicle parking requirements to zero on-site car parking with the exception of disabled and car club parking. This permitted increased site yield ('a planning gain mechanism'). The sustainability cost premium was partly absorbed by the higher yield on the small site resulting in an increase the number of apartments from a permissible 80 to 172 units (internal rate of return was approximately 15%) (Sustainability Victoria, 2011).

The developer (Bioregional Quintain) also introduced the role of 'sustainability integrator' to ensure the sustainability principles were 'integrated seamlessly from design through construction to estate management'. A 'long term estates management strategy' was developed to manage the integrated environmental systems post-sales at which point the sustainability integrator handed over to a site caretaker to continue to ensure the smooth running of the long term estates management strategy. Given the use of unconventional sustainability technologies in most low carbon precincts, ongoing maintenance is critical for long term success.

To help monitor suitable products BioRegional also developed a not for profit service called 'One Planet Products' that assesses products and suppliers against the One Planet Principles to catalogue a 'green' supply chain permitting efficient selection of the most appropriate products and suppliers (see http://www.oneplanetproducts.com/). The service helps spread knowledge within the construction industry and increases sales and market penetration for green products (hopefully also reducing costs of green products over time as an economy of scale).

Assembling the right team was essential to the success of One Brighton. The developer and builder consortium were value-driven and include some of the UK's most sustainable practices. The development was almost entirely funded through private finance (with minor renewable energy grant subsidies). By aligning project objectives with the consent authorities high level sustainability objectives the proponent was able to submit a non-complying scheme and argue for merit based planning gain to make the sustainable scheme financially viable.

Vauban, Germany

The 38 hectare Vauban neighbourhood completed in 2006 is the greenest quarter of Germany's 'ecological capital' – Frieburg. The City of Freiburg helped facilitate and empower residents through an interesting model of community participation through a community engagement platform, Forum Vauban. Forum Vauban, working in collaboration with the City of Freiburg, developed a community vision that sought to balance environmental, social and economic goals to guide future development (Forum Vauban, 2004). The city council set requirements, boundaries and incentives such as reduced tax on land acquisition, to help implement the vision.

As a result of this process the neighbourhood includes a range of sustainability measures including high density and mixed use services concentrated along the tram route and bus corridors, a comprehensive cycle and pedestrian network (in addition to low trafficked streets) and high performance building requirements.

A key element enabling the cost effective implementation of this vision was the establishment of 'construction communities' (owner-developer collectives of 3-21 households in size) based on the co-housing concept where a group of individuals with a common vision for living formed a co-operative to develop apartment buildings on their terms. Because construction communities are owner occupiers a number of these developments exceeded the high building standards required by the council, with a 100 dwellings built to the PassivHaus standard and 59 dwellings that exceed this to add energy back to the grid as 'plus energy houses' (Forum Vauban, 2004).

By cutting out conventional developers driven by a profit motive, collectives of several households with a common vision work together to build apartments or a city block to their own specifications. Similarly, community funded decentralised energy allowed residents to simultaneously invest in their local community and receive income as dividends from energy sales.

Community and owner-occupier investment has the advantage of removing much of the financial burden from government while allowing the local government approval processes to ensure developments to meet minimum criteria relating to sustainability performance and social responsibility based upon the values that emerged from the community engagement. Funds that might ordinarily have been absorbed by the developer's profit margin are able to be invested in sustainable technology overcoming some of the sustainability cost premium.

Peterborough Carbon Challenge, UK

The Carbon Challenge was a UK government initiative that saw the public sector working with private developers to 'accelerate innovation' (English Partnerships, 2007). Peterborough was the larger of the two Carbon Challenge projects ultimately realised. Both projects were supported by heavy government subsidies and led by the English Government's national regeneration agency English Partnerships. English Partnerships maintained that the projects were necessary:

> *…in order to develop the skills and technologies in the house building industry that are necessary to deliver new zero carbon homes at Level 6 of the Code for Sustainable Homes. The Carbon Challenge will make house builders and their suppliers better prepared to meet the Government's goal that all new homes will be zero carbon by 2016.*
> English Partnerships, *Carbon Challenge Standard Brief* (August 2007)

The Peterborough Carbon Challenge project consists of 295 dwellings (including a 40% affordable housing), a centrally located office and community space within a seven hectare brownfield site is in the historic city of Peterborough (Opportunity Peterborough, 2011). This public private partnership was led by English Partnerships in conjunction with development authority 'Opportunity Peterborough' and other government stakeholders. A competitive tender process resulted in the winning team being awarded subsidised land sale to absorb the additional risk and costs associated with innovative sustainability measures.

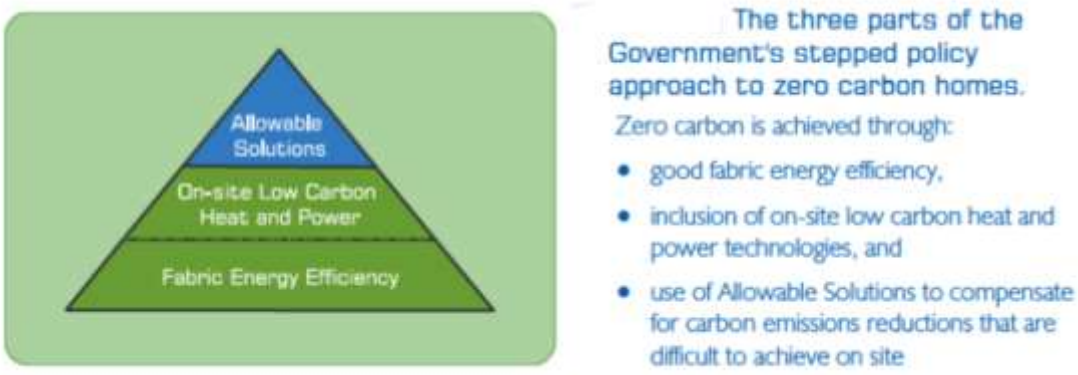
Currently under construction, Peterborough Carbon Challenge, will be the UK's largest zero-carbon, mixed-use development when completed (Peterborough City Council, 2011). The Carbon Challenge benefits industry and government by testing the policy and highlighting opportunities and weaknesses that need to be addressed. It also enables the community to understand what a 'zero-carbon' community can look like (Department of Homes and Communities, 2011).

The driver for government involvement in the project was the *Code for Sustainable Homes* (CSH) released in response to the 'Stern Review' recommendation for the government to take early and strong action on climate change to minimise future social and economic disruption. When the code was released in 2006, however, no existing housing development could satisfy the aspirational future code requirements therefore the Carbon Challenge was developed as a pilot program to demonstrate that zero-carbon housing was possible, to showcase excellence in sustainable urban development and initiatives and also to test and monitor new ideas.

The winning scheme included highly insulated buildings (reaching PassivHaus standard), combined heat and power plant, water sensitive urban design and integration of urban ecology on a constrained site, on-site food production including small orchard plantings and allotments and a community café that will sell locally produced goods (RUDI, 2008; Department of Homes and Communities, 2011).

Lessons from the Carbon Challenge have lead to a modification from the initial prohibitively expensive requirement for all energy to be produced on site, to a more cost-effective approach that ensures new development delivers high building fabric energy efficiency with more lenient 'on-site' energy requirements (see Figure 2) with any further carbon emission reduction requirements able to be compensated by 'allowable solutions' (off-site).

Figure 2: The three parts of the UK Government's stepped policy approach to zero carbon homes.
Source: *Zero Carbon Strategies*, Zero Carbon Hub (2013)



The 'carbon challenge' was a useful process for the UK government, providing demonstration projects to showcase new technology and 'accelerating innovation' within the private sector to help meet national emission reduction objectives. More importantly, however, it allowed rapid prototyping and testing of policy outcomes, ultimately leading to the revision of an onerous and costly burden upon the developer to meet all their renewable energy needs 'on-site'. The amended policy shifted the emphasis toward the creation of highly efficient building envelopes to reduce energy demand from housing stock. The generation of on-site renewables while encouraged, may also be met be 'allowable solutions' off-site (Zero Carbon Hub, 2011).

Lessons learnt from the Carbon Challenge process and subsequent research have been collated and maintained in a central repository – the 'Zero Carbon Hub' – a public private partnership

‘established to take day-to-day operational responsibility for coordinating delivery of low and zero carbon new homes’ with the strategic objectives to: create confidence during change, reduce risk and clear obstacles, disseminate practical guidance (Zero Carbon Hub, 2008). This knowledge sharing portal helps disseminate lessons to government, industry and community accelerating uptake of knowledge relating to the building sector and helping to overcome the skills barrier.

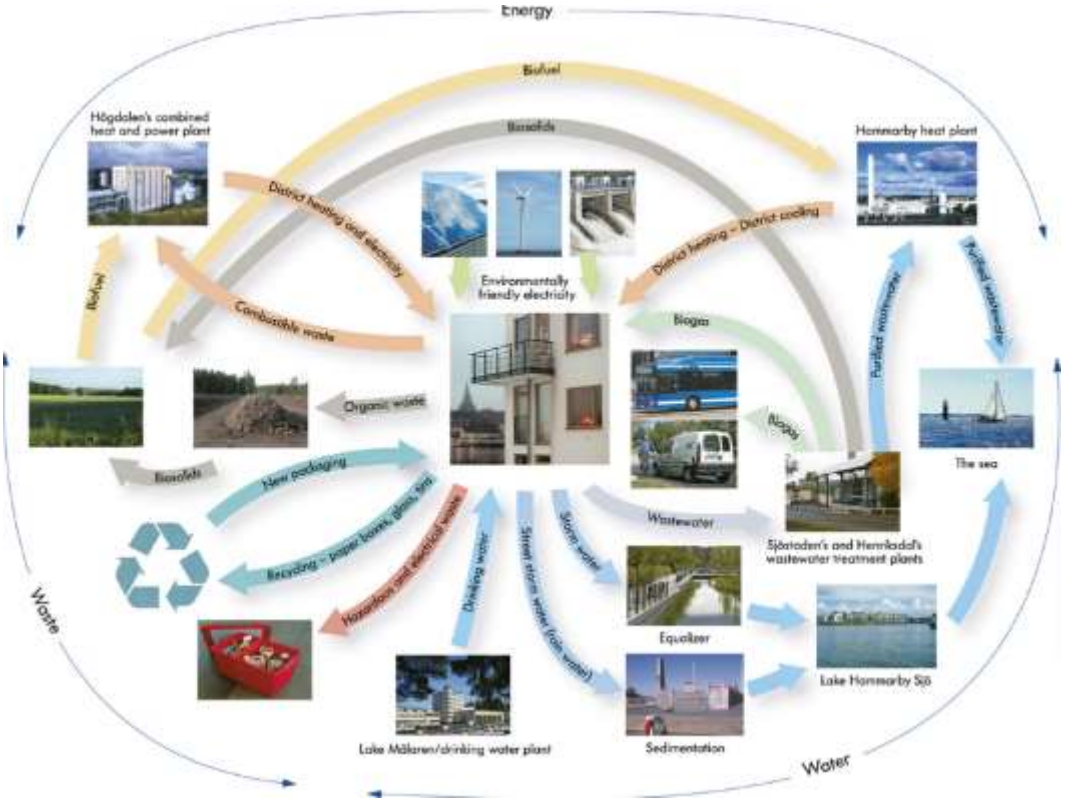
Hammarby Sjostad, Sweden

Hammarby Sjostad is a 200 hectare medium to high density neighbourhood in central Stockholm that is the result of a public private partnership to redevelop a former naval yard into a showcase sustainable neighbourhood. The project, catalyzed by the unsuccessful 2004 Stockholm Olympic bid, when complete in 2016 will include a mix of land uses including 10,000 dwellings, office, retail and community space. A special feature of the redevelopment is the high quality public realm which maximises the existing site assets and includes a long water frontage activated by harbourside walks fronted by restaurants and cafes (Energy Cities n.d.).

The development aims to achieve a 50% reduction in emissions and waste from a 1990s baseline established by surrounding communities through a series of ‘integrated sustainable systems’. The series of integrated sustainable systems are summarised in the ‘Hammaby (metabolic) model’ (shown in Figure 3) (GlashusEtt, 2007). This is a holistic approach to urban services that increases efficiency by taking advantage of interdependencies between energy, waste and water management cycles.

The Hammarby model recognises that ‘everybody who lives in Hammarby Sjostad is part of an eco-cycle’ that includes energy, waste, sewerage and water for both housing and offices (City of Stockholm, 2013). Development of the model required close collaboration between the various government agencies to close these loops as much as possible such that waste is not treated as pollution but rather as a resource. An example of the Hammarby Model eco-cycle is the incineration of combustible waste to produce both electricity and district heating in the precinct wide district heating network (GlashusEtt, 2007).

Figure 3: ‘The Hammarby Model’.
Source: GlashusEtt (2007)



Hammarby Sjostad is exceptional in that it not only demonstrates innovation in project delivery but it also showcases innovation regarding integrated public services. Service agencies usually function within their own 'silo' largely a result of discrete funding streams that bring about a disregard, disinterest or disempowerment to engage with other agencies. What we see at Hammarby is public agencies being provided a mandate to work together to seek mutually beneficial synergies that result in resource efficient industrial ecology – the 'Hammarby Model'. This model serves to reinterpret waste streams as resources to largely close the neighbourhood's urban 'metabolic loop' at the precinct scale.

City of Berkley PACE, USA

In 2008 the City of Berkley, California, introduced an innovative financing tool that allows property owners to receive full funding to retrofit homes with sustainable measures thus overcoming the split incentive through the Property Assessed Clean Energy (PACE) model (City of Berkley, 2008). PACE loans are repaid via a local government or state property tax tied to the property over a specified period (e.g. 20 years) (cf. Environmental Upgrade Agreements (EUA) Sustainable Melbourne Fund). This model allows households to overcome the 'split incentive barrier' that sees the developer without incentive to invest in sustainable technologies because the benefits are passed onto the new occupant. Conversely the new building owner is often not in a financial position to meet the large upfront investment in sustainable technology (e.g. PV cells) despite the likelihood that such an investment may save them money in the long term. PACE allows this barrier to be overcome and with the reduced utility costs can save the occupant money over time. The Berkley model has been widely replicated across the US and is now in use in 31 US states (PACE Now, 2013).

PACE works well for single owner occupied buildings but another split incentive barrier exists for rental and multi-family buildings where the owners may be reluctant to pay for sustainability improvements they can not recoup from tenants. A 2013 pilot project overcomes this through On-Bill Repayment (OBR) which allows owners to repay loans through monthly utilities bills (Kim et al. 2012).

Both the PACE and OBR models are aimed for individual buildings but it would be a small step widen this to the precinct scale to encourage decentralised energy systems particularly for regeneration or new build projects. A Greening, Revitalisation and Improvement District (GRID) concept has been proposed by Rauland (2013) as a model for funding precinct scale eco-infrastructure and the PACE and OBR models may provide the financial template for this to occur.

Conclusions

A holistic approach to urban environments (be they greenfield, brownfield or greyfield sites) at the precinct scale provides the opportunity for eco-infrastructure development at a scale of efficiency not able to be achieved at the individual building level. Precinct scale development may provide the best opportunity for incrementally decarbonising Australian cities short of comprehensive policy change or institutionalised financial incentives at a national level.

Political, skill and market barriers exist that inhibit sustainable urbanism. Lessons from the international low carbon precinct case studies presented here may help develop pathways to overcome these barriers as Australia transitions toward low carbon sustainable urbanism practices.

The UK government, by coupling policy (*the Code for Sustainable Homes*) with funding for demonstration projects (the Carbon Challenge), were able to overcome the time lag usually associated with incremental policy through 'rapid prototyping' of a end state (the Carbon Challenge demonstration projects). The Carbon Challenge was good for public relations gaining industry and public attention but it also served to accelerate innovation in the UK built environment sector by expanding the building sector's knowledge and skills base. Feedback from the demonstration projects led to policy review and also knowledge dissemination through monitoring and recording of lessons with a repository of information being managed online through the 'zero carbon hub'. The zero carbon hub acts as a one-stop knowledge bank increasing accessibility to technical information thereby quickly reskilling the UK building sector to deliver energy efficient buildings and low carbon decentralised energy in the built environment.

Government can also restructure agencies to overcome a siloed approach to services that lead to inefficient resource use in favour of processes that permit agencies to work in an integrated manner by encouraging waste reuse to reduce the 'metabolism loop' of urban processes as seen successfully applied in the 'Hammarby Model'.

An entrepreneurial approach to the planning system as demonstrated by BioRegional's developments BedZED, and in particular, One Brighton, saw the developer apply 'the planning gain mechanism' to great effect negotiating development floor area bonuses from consent authorities as a result of project merit. The sale of the additional floor area translated into greater development returns to offset the 'sustainability cost premium' to make sustainable development competitive in a conventional market place.

The sustainability cost premium can be overcome by an informed and proactive community such as in Vauban where community involvement in Forum Vauban allowed collaboration with city authorities to deliver innovation in new development. Owner-developer co-operatives allowed like-minded individuals to take on the role of property developer and cut out the developer profit margin (usually 5-15% of total project costs) with this budgetary saving reallocated toward sustainability or liveability measures to benefit home owners and broader community.

For retrofit projects or where other initiative are not feasible the introduction of PACE and OBR schemes can be used to overcome split incentives to finance clean energy and other sustainability initiatives.

A consistent factor of all the discussed case studies was a strong and clear sustainability vision described at the outset along with commitment to see the vision through to project delivery.

Invariably this involved dedicated stewardship, although the form of the steward varied and included development authorities (Peterborough), ‘sustainability integrators’ (One Planet – BedZED, One Brighton), local councils (Hammarby Stojstad, Berkley PACE) or community groups (Vauban).

Ultimately visionary leadership, stewardship and integration between stakeholders will be required to decarbonise Australian cities particularly when faced with political, financial and skill based barriers to sustainability innovation within the built environment. As cities seek to transition toward low carbon communities, precinct scale development provides opportunities for experimentation by being large enough to allow integrated eco-infrastructure and service provision efficiencies, yet, small enough to permit effective local governance that ensures sustainability stewardship. The examples of precinct scale sustainable development presented here offer ways to overcome some of the political, skill and market barriers that currently exist in Australia and are inhibiting the uptake of sustainable urbanism.

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