Empowering Broadway

Phase 1 Research Report

Prepared for - CRC for Low Carbon Living

Empowering Broadway

Co-operative Research Centre for Low Carbon Living

Phase 1 Research Report –Final

CRC LCL Project RP2018: Retrofitting Urban Precincts to Create Low Carbon Communities

Client: CRC for Low Carbon Living

Prepared by AECOM

In association with AECOM, BROOKFIELD, FLOW SYSTEMS AND UTS

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Executive Summary

The Empowering Broadway research project's purpose is to enable low carbon energy and water transitions for existing urban communities in Australia's growing cities. If we are going to enable a low carbon future it will be critical that we learn how to transition existing urban systems ageing water and power infrastructure to flexible, resilient and sustainable networks.

Emerging research and global best practice is demonstrating that empowering communities to form precincts, develop local water and energy solutions is both lowering utility costs and carbon reduction. Emergent technologies and business models in the energy and water sector along with the managing a changing climate will drive a step change in how these services are configured and consumed.

We are undertaking research to better understand existing precincts, create business cases and implement the technologies and governance models required to transition to a low carbon community. This research seeks to empower stakeholders within communities to drive transitions to low carbon energy and water use, by providing them with the data and processes they need for change.

The following highlights, barriers, opportunities and next steps are identified through the research.

1.1 What are the Barriers?

There are many barriers to precinct scale transitions. The status-quo is enforced by a range of local , national and global factors such as :

- It is generally far easier to manage most aspects of energy efficiency and technology solutions on a building by building basis where the governance issues are far simpler.
- Currently regulatory framework around regulated assets such as distribution networks inhibit efficient management of local infrastructure across property boundaries.
- Collaborative and collecting processes would likely deliver higher order results, however are difficult to orchestrate and typically occur organically.
- Roof space availability is a major constraint to adoption of solar resources at a medium density or existing precinct scale.
- Significant investments of time required by the private sector to inspire a transition without any certainty of potential payback.
- The technology landscape is moving so fast that large capital investments are difficult without significant future-proofing, however it is difficult to envisage what that future proofing may look like.

1.2 What are the opportunities?

- Opportunities revolve around economies of scale.
- Combining off-site generation with local management and control.
- Combining trading into the wider market with local management and control.
- New technologies may catalyse new models at a precinct scale and make existing models more economic.
- Social media may power new forms of collective action.
- New business models may catalyse new regulatory frameworks.
- Development of data tools that enable sharing of data and exploration of opportunities, while protecting privacy.
- **Reducing development risk** - a method to achieve greater economies of scale in infrastructure provision by understanding and integrating demand, efficiency and supply in a coordinated way: reducing consumption, capital cost and operational cost.
- **Enabling yield impacts** – If development yield is limited by infrastructure constraints then enabling more efficient of sustainable infrastructure effectively

captures land value through efficiency and infrastructure solutions. This can managing infrastructure risks to a developer though efficient alignment of demand and supply.

1.3 Is the precinct scale the most appropriate for solving these issues?

In this report we explore precinct technologies, governance concepts, and existing relevant technologies as we explored the benefits and barriers of operationalising carbon efficiency based on a precinct retrofit. Some of the key insights from the report :

- There are few real examples of successful retrofitting of existing precincts with the specific aim of decarbonisation.
- There are a number of traditional technologies , such as district heating and cooling networks, that can reduce carbon intensity of a precinct, however there are opportunities for new technologies such as microgrids to improve low carbon outcomes. These technologies are embryonic at this stage, and heavily dependant on legislative changes.

1.4 Next phase of the research

- **Management of fragmented land ownership** – provides a toolkit which describes how to manage a range of stakeholders with different drivers into a governance and economic model to enable infrastructure realisations and efficiencies: shared economy or collaborative consumption.
- **Research into microgrids** – the area of microgrids with regards to precinct migrations is ripe of new research.
- **Regulatory –** investigation into new enabling regulatory mechanisms.
- **New standards :** Undertaking the literature or a meta-data study of low carbon precinct initiatives and standards to support the new National Carbon Offset Standard (NCOS) committee tasked recently with extending the existing standard to include buildings, precincts and cities.

1.5 How do we start the great transition?

This report summarises the emerging low carbon technologies, local infrastructure data and international case studies to explore the low carbon solutions possibilities for Sydney's Broadway Precinct. This is the Phase 1 Report and provides a summary of the first stage of research, conducted in 2015 and early 2016. The long-term goal of the project is to set in place improved understanding to induce an urban transition toolkit which will assist precinct stakeholders to create successful low carbon infrastructure.

1.0 Introduction

This report explores the potential solutions for transitioning existing precincts to be lower carbon through collaboration on engineering solutions, financial models and governance approaches. The report focuses on Sydney's Broadway Precinct, a precinct which includes two major educational campuses with strong sustainability drivers and a new residential / retail development that includes a district heating and cooling plant. This report provides a summary of the first stage of research, which was conducted in 2015-2016.

The long-term goal of this research is to enable low-carbon transitions through considering emerging technical, governance, financial and policy frameworks in order to enable the development of a future urban transition toolkit which will facilitate precinct stakeholders to successfully regenerate and transform existing. The research plan envisages two phases: Phase 1 of the research is focused on setting the context and baselines for the research and how the Broadway precinct could transition into a Living Laboratory; subsequent phases may be focused on options and scenarios development and documentation of transition pathways. This Phase 1 report has uncovered a number of significant challenges which will form the basis of any further research.

Phase 1 was split into two key research streams; one stage was around undertaking global best practice review of technologies, governance and financial models used on transitioning precincts and the second stage was around developing a detailed model for Broadway. The detailed model encountered several challenges which included obtaining access to data, ensuring data quality and changes in stakeholders during the research period. In order to complete the data model, more assumptions than initially planned were considered which affected the reliability of the results in an unforeseen way. However, the research team believe that, given the use of mixed methods of research the recommendations and next steps are sound and appropriate.

1.6 Empowering Broadway

The 'Empowering Broadway' research project aims to enhance knowledge towards lower carbon, energy and water solutions currently available to communities in Australian cities. There are major economic, social and environment benefits possible for communities that transition their ageing water and power infrastructure to flexible, resilient and embedded networks or collaborate to drive efficiency across stakeholders and assets.

The project specifically aims to identify and understand the economic, social, regulatory and technical barriers to transitioning entire precincts and devise viable pathways for stakeholders to successfully adopt new models by facilitating community understanding of the opportunities offered by low carbon energy and water solutions.

The research focused on better understanding existing precincts, developing business cases and defining the technologies and governance models required by communities to transition to low carbon precincts. The research seeks to empower stakeholders within communities to drive transitions to low carbon energy and water use, by providing them with the data and processes they need for change.

These transitions have not been successful to date, and research is urgently needed to improve our knowledge and enable the delivery of precinct efficiencies with suitable infrastructure. The CRC Low Carbon Living aims to begin this international journey by examining Sydney's Broadway Precinct[1].

This research seeks to identify the opportunities and blockages in such transitions through a living laboratory approach (using Broadway precinct in Sydney) to then identify widely applicable typologies that may enable such a transition to be applied to any precinct . Emerging research and global best practice is demonstrating that empowering communities to form precincts and develop local water and energy solutions is delivering both lower utility costs and carbon emissions reductions. Emergent technologies and business models in the energy and water sector along with the realities of managing a changing climate will drive a step change in how these services are configured and consumed.

The research is particularly relevant given the March 2016 Federal government decision to expand the National Carbon Offset Standard (NCOS) to buildings, precincts and cities, from the existing domains of businesses, products and services. Once developed, the standard will enable property to claim Carbon Neutrality using a government endorsed standard which will reduce confusion around definitions and accounting methods. This follows on from Curtin University's proposed standardised framework, to recognise the environmental benefit of low carbon infrastructure solutions. They highlighted a gap in the market, that enables claims for technologies and programs to be credited with 'carbon credits' but not precinct-scale low carbon solutions (Bunning, J., Beattie, C., Rauland, V., Newman, 2013). Several carbon abatement credit schemes exist in Australia – refer to Section 3.1. Potential partnerships with international organisations promoting sustainable community precinct development include Curtin University Sustainable Policy Institute, EcoDistricts and Climate KIC and their Smart Sustainable Districts Flagship.

1.7 The Challenge: Low Carbon Urban Systems

Over half (54 per cent) of the world's population currently lives in urban areas, a proportion that is expected to increase to 66 per cent by 2050 (UNDP, 2014). Although most of this growth will be in low and middle-income countries, it is still forecast that around 1.2 billion people will be living in cities in high-income countries including Australia by 2050 (WHO 2014). This trend of urban versus rural living is unprecedented in history and has significant implications for managing resources sustainably. There is a significant need to rapidly scale up sustainability innovation and generate long-lasting solutions to the complex resources management challenges facing cities, particularly regarding carbon emissions reduction.

A compelling economic case for cities in both developed and developing countries to invest, at scale, in cost-effective forms of low carbon development, for example in building energy efficiency, small-scale renewables and more efficient vehicles and transport systems. An analysis of five global cities (SEI, 2014) found that these types of investments could result in significant reductions (in the range of 14-24% relative to business-as-usual trends) in urban energy use and carbon emissions over the next 10 years, with financial savings equivalent to between 1.7% and 9.5% of annual city-scale GDP. Securing these savings would require an average investment of $3.2 billion (US) per city, but with an average payback period of approximately two years at commercial interest rates, demonstrating that large-scale low carbon investments can appeal to local decision-makers and investors on direct, short-term economic grounds. They also indicate that climate mitigation ought to feature prominently in economic development strategies as well as in the environment and sustainability strategies that are often more peripheral to, and less influential in, city-scale decision-making.

Recent attention on the sub city-scale, focusing on neighbourhoods and precincts provides different challenges and opportunities than across a whole city. With benefits including localized economic development, community cohesion and liveability being enhanced through local action. Global best practice is demonstrating that empowering communities to form precincts and develop local water and energy solutions is delivering both lower utility costs and carbon emissions reductions.

Numerous low carbon technologies and system innovations already exist, and continue to emerge, which provide an indication of the future possibilities for low carbon, high-density urban precincts. Some are well established to provide significant contributions in the near-term such as thermal networks or co-generation systems, and others are in research or development stages of maturity and may not breakthrough to mainstream commercial availability in the near-term. The range, pace and depth of activity in this space globally paints a picture of a radically different future for the urban environment and how resources are viewed and used.

It is acknowledged that technological development in and of itself will not deliver global GHG emissions reductions targets or radically improve the use of potable water for sanitation and drinking. Technologies are just one part of a complex socio-technical system that is shaped by individual and societal values, cultural behaviours and practices that interact with, influence and are influenced by the physical environment (Geels and Schot, 2007). A range of actors will have influence on various stages of technology research and development, commercialisation and implementation, helping to scale up various technologies at different rates thereby co-creating the future. The role of well-informed policy-makers, industry and other stakeholders is therefore crucial in driving change to shift ingrained patterns of energy consumption and to address energy and water security and sustainability, change systems by design, rather than just by events (IEA, 2014).

City and regional governments are ideally placed to lead and drive precinct-scale sustainability activities, however a collaborative approach between developers, utilities, building and business owners and residents is needed for the deep cuts in emissions to be realised. These collaborations and new modes of working should address the existing barriers that need to be overcome to enable precinct-scale infrastructure, such as initially higher capital costs. Demonstrated benefits of precinct-scale energy, for example, include the effective lowering of peak demand, and limit fixed utility charges by reducing the number of connections.

Precinct energy and water utilities are significantly influenced by the context in which buildings, public domain and infrastructure profiles sit. These systems create a sense of "place" and drive the evolution of systems, standards and technology. Utilities also operate within an increasingly dynamic environment of rapidly evolving technologies, business and policy structures linked to how services such as water and energy may be delivered in the future (e.g. centralised, distributed, hybrid). However, in the Australian electric power industry, the centralised energy system including the NEM, networks and retailers has been slow to adapt to the changing context – rapidly reducing demand, the rise of solar and the rapid development in storage meaning that real innovation on the fringes of the network will increasingly determine its future direction.

1.1 The Broadway precinct and stakeholders

The Broadway Precinct at the centre of this project is a high-density, inner city precinct in Sydney, which, for the purposes of this project, has been defined as incorporating University of Technology Sydney (UTS), TAFE NSW and Frasers Broadway – Central Park. Figure 1 shows the precinct boundaries.

Figure 1 Broadway Study Area

The precinct includes educational facilities, retail, residential and commercial assets. The focus on Broadway Precinct seeks to provide an understanding of potential technologies, business cases and governance structures to enable complex precincts to transition and grow while minimising costs and carbon emissions impacts associated with this growth. The use of Broadway within this research will be to provide the systems and knowledge to enable the retrofitting of existing urban infrastructure and utilities and set up Broadway as a Living Laboratory to enable future research.

1.2 Phase 1 Project Purpose and Scope

Phase 1 of the research focused on setting appropriate context and baselines. This phase was undertaken using a mix of quantitative (infrastructure data collection and analysis) and qualitative (case study) methods.

This phase focused on getting an understanding of the key constraints and opportunities, stakeholder needs, global practice to then develop a baseline model for the Broadway Precinct. It is focused on identifying the existing baseline for:

- Governance and stakeholder value,
- Economics and finance,
- Global best practice, and
- Infrastructure and utility consumption

Whilst the research focused exclusively on the Broadway Precinct, the baseline research and analysis is cognisant that the outputs will be broader than the Broadway Precinct. The intention was to identify key stakeholders with active sites within other active precincts either in NSW elsewhere in Australia.

This Phase 1 of Empowering Broadway provides:

- Insights from a review of global best practice in governance and applicable technologies,
- An appreciation of precinct typologies to be applied to future research streams,
- A full baseline scenario for energy and water in the Broadway Precinct, and
- An understanding of stakeholder drivers and needs.

This research includes a global scan and evaluation of potential systems and technologies that are likely to enable low carbon precinct-scale outcomes into the future. In particular, we explore electricity supply and demand, heating, cooling and water provision technologies for high-density, urban precinct retrofits that are likely to have significant influence out to the year 2040 in the context of precinct-scale applications.

At this time, there are radical shifts under way in the Australian and international energy markets in particular, with new technologies and enablers coming together with strong demand for change from consumers and the global community – this means that any future-focused work is limited in its capacity to predict technology winners. Our approach intendeds to provide an overview as a basis for further detailed analysis of specific precinct contexts, rather than as a standalone prediction of a future scenario.

The Broadway scenario therefore provides a detailed set of baseline information about the stakeholders, governance structures, relevant assets and utility consumption across three major stakeholders. As part of the Phase 1 research was to explore how some of these global best practice models could be applied over the Broadway Precinct and where the barriers or local research challenges existed.

1.4.1 Exclusions

The research is focused on stationary energy consumption and water consumption within the precinct and how to transition this over a medium term time frame to more optimal consumption patterns. The research does not consider the implications of embedded energy in materials, waste or transport energy consumption.

The following paragraphs outline the consideration of these variables.

Transport energy and related technologies have been excluded as they are not in the direct control of the stakeholders and carry significant externalities .However, the potential impact of electric vehicles uptake has been considered due to the potentially significant impact on the grid/electricity system and as locators of storage potential. It is recognised that transport is an important consideration for precinct carbon benchmarking however does not form part of this study.

Consideration around embedded energy in building materials has also been excluded, although we anticipate significant advancements in life cycle analysis of products and materials during the next twenty-five years to enable cradle-to-cradle thinking.

In addition, some technologies that are in very early stages of research and development were excluded from this analysis and, due to the nature of the complexity of the system, there may be some technology likely to emerge as significant over the coming decades.

1.4.2 Project Team

The following graphic highlights the key stakeholders who have been involved with the research project within phase 1.

Figure 2 Research stakeholders

The following table identified from the research outset that each of the research partners had different drivers / interests in the research.

Table 1 Research stakeholders and research drivers

Team Members	Proposed goals / research drivers
Brookfield/ Flow	• Be a change catalyst for new markets. • Enable precinct scale infrastructure at Central Park.
City of Sydney	• Enable the Cities for distributed energy and water master plans. • Research to enable and report on low carbon precincts. • Leverage and extend existing research agendas. • Work towards the goal of reduced GHGs by 70% in the city by 2030.
Sydney Institute of TAFE	• Facilitate upgrade plans for facilities and potentially realise improved economies of scale. • Leverage existing research. • Understand requirements, skill demand and need for vocational education training. • Support a program for minimisation of own carbon footprint as a key corporate goal
AECOM	• Gain an understanding on facilitating the low carbon retrofitting of urban areas
UTS	• Facilitate a low carbon transition of assets and utilities. • Leverage existing research, systems and technologies. • Advance research. • Work towards a 30% reduction in carbon emissions by 2020-2021.
Better Building Partnership	• Move to the next stage of research to enable plug and play precincts.
Urban Growth	• Support the current direction for urban regeneration. • Lower the infrastructure risks and costs associated with urban development.

1.4.3 Phase 1 Method

1.4.3.1 Stakeholder baseline

This stakeholder baseline process focused on identifying the existing networks, knowledge, behaviours and decision-making processes affecting the precinct utilities at Broadway. That is, obtaining an understanding of the existing context, drivers, barriers, risks and opportunities for stakeholders within the Broadway Precinct and carry out:

- A stakeholder engagement strategy,
- Stakeholder visioning workshops,
- Stakeholder analysis and benchmarking, and
- Key stakeholder interviews.

1.4.3.2 Global best practice review of precinct retrofitting

A global best practice review focused on identifying similar precinct solutions elsewhere in Australia or globally with particular attention to the governance structure and transition process. This comprised the identification and review of:

- Precinct transitions / staging processes,
- Regulatory frameworks,
- Commercial models,
- Project specific drivers (policy, financial, governance, etc.), and
- A review of failed projects and evaluation of the key risk factors.

1.4.3.3 Precinct system / technology evaluation & forecasting

Phase 1 reviewed existing and emerging systems and/or technologies that could support a low carbon precinct solution. It included the following:

- Identification and profiling of systems and/or technology and their related applicability to a precinct solution,
- Current commercialisation status, and
- System and/or technology projections / forecasts.

1.4.3.4 Baseline model of the Broadway Precinct

This stage developed a detailed model of the base case assets, utilities consumption, costs and environmental factors. This provided a base against which future options and scenarios can be compared as well as the following:

- Asset review of
  - Precinct utility,asset review and reporting standards,
  - Building and precinct,
  - Asset profiles,
  - Efficiency measures & standards applied,
  - BMS / Mechanical systems, and
  - Asset age, replacement schedule & cost.
- Utility review of
  - Energy (i.e. electrical, thermal and mechanical) – including costs, where possible,
  - Water (i.e. potable, non-potable, stormwater and waste) - Including costs, where possible,
  - Building, tenant and public domain,
  - Energy & water assets and liabilities,
  - Operational assets and liabilities,
  - Consideration of 24 hr, seasonal and annual cycles, and
  - Provision of a full baseline model based of a 2014 form and usage profile.
- Governance review of
  - Existing formal and informal networks, regimes, governance models and drivers, Level of influence over demand and supply, and,
  - The development of a baseline lifecycle cost and environmental impact model for the Broadway Precinct (including Carbon).

2.0 Transitioning low carbon energy and low carbon water precincts

Definitions of low carbon precincts, systems and networks vary. However, “Green infrastructure” is a term becoming popular to describe low carbon infrastructure. Bunning et. al. define “green infrastructure” as “alternative ways of supplying power and water and treating wastewater and solid waste that can help to achieve sustainability outcomes and reduce emissions” (Bunning, J., Beattie, C., Rauland, V., Newman, 2013).

Carbon

The term low carbon is used to describe the minimisation of carbon dioxide and other greenhouse gases emissions. For this project, low carbon solutions are specifically aligned to opportunities in the built environment in a manner that supports improved efficiencies or more sustainable infrastructure and utility services.

Low carbon energy and low carbon water solutions are commonly based around decentralised or distributed systems, which use smaller scale systems at a local precinct level. These systems often replace or reduce the need for individual building systems and can reduce the reliance on city wide infrastructure such as grid electricity. Low carbon centralized solutions are designed to be more efficient and environmentally sustainable.

Curtin University summarises the current concerns as:

“Despite the widespread use of the new carbon terms within the public domain, no widely accepted international certification system has been established for recognising achievements in carbon reduction… While the broad intention of the terms is to describe an atmospheric carbon reduction relative to the inputs and outputs of a product or service or, in this case, a city precinct, an increasing number of carbon terms—e.g., those including zero, negative, positive, free or neutral—go beyond describing a mere reduction. Instead, these terms define a development that has no net carbon associated with it.” (Bunning, J., Beattie, C., Rauland, V., Newman, 2013)

The process to claim a product, building or precinct is carbon-neutral is typically designed to:

- Collect data to measure a discrete set of emissions,
- Design and implement strategies to reduce these emissions, and
- Offset the remaining “unavoidable” emissions.

Water

Although water is a renewable resource, its supply is limited by local catchments, availability and distribution systems. Across Australia these are significantly affected by periods of increasingly unpredictable drought, which creates supply constraints and drives the need to consider alternative supply sources. Within precincts, water provides a large range of services from drinking and cooking, cleaning and irrigation to provisioning toilet flushing, cooling towers and swimming pools. These services also generate significant amounts of waste water and the precincts are catchments for rain water which can form part of the local supply needs. In order to manage, and possibly anticipate, the variability of supply while also reducing the reliance on the network, there are opportunities to explore alternative water supplies at this scale.

This report seeks to identify the potential low carbon transition pathways within a precinct and is considering both energy and water in that context. There are many points at which the energy and water systems meet at a precinct scale. An example may be the decision to look at an Air-cooled or Water cooled chiller for the HVAC system. There is both an energy and water impact associated with this choice and both need to be considered together.

Another example would be where a central energy plant and a water recycling facility are co-located. There may be opportunities to optimise the running of the energy and water systems to best optimise the peak demand / supply cycle across the precinct. This could lower the carbon intensity of the energy supplied to the development as well as the embodied carbon element of the water.

From a water / carbon perspective, the carbon intensity of supply needs to be well understood to firstly enable effective benchmarking and, subsequently, low carbon transitions. Each water supply source requires an element of energy consumption as a result of its collection, treatment or distribution phases. It also requires energy in its disposal and waste treatment phases. In addition to this, there are direct emissions from waste water (e.g. methane) and emissions from construction / works / maintenance that need to be considered. Depending on these sources and the carbon intensity of the energy use involved, the water effectively holds a carbon footprint per litre. The following chart shows the total Sydney Water carbon emissions trends over the last 8 years.

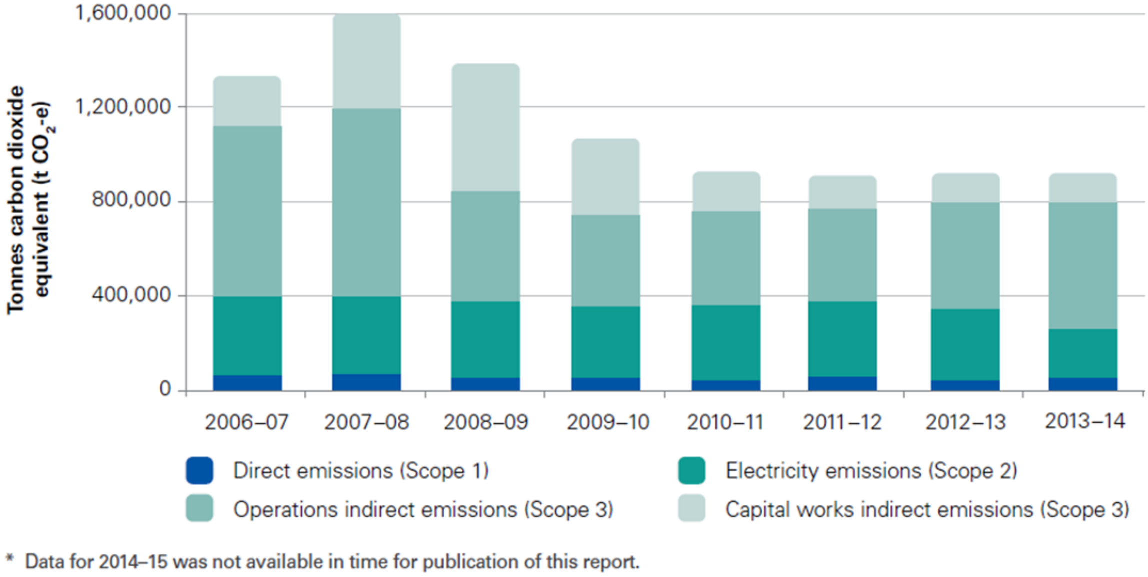


Figure 3 Sydney Water's carbon footprint trends 2006-07 to 2013-14

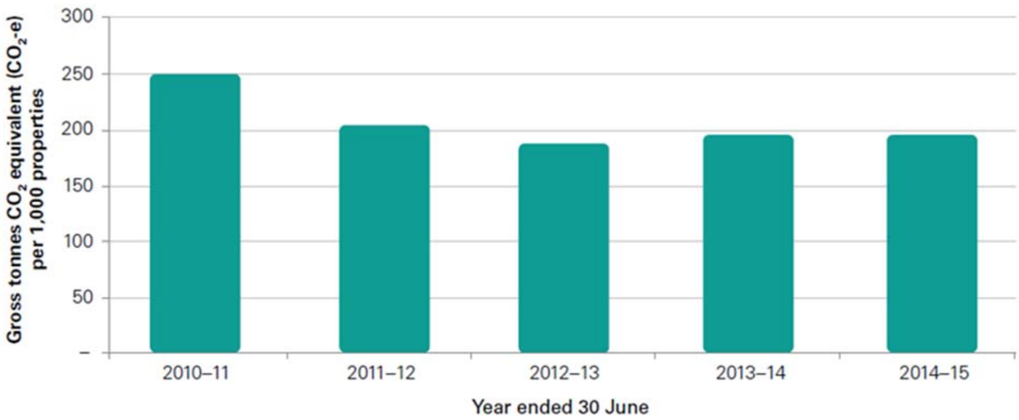


Figure 4 - Sydney Water's total gross greenhouse gas emissions per 1,000 properties 2010-2015

Source: http://www.sydneywater.com.au/web/groups/publicwebcontent/documents/document/zgrf/mdc4/~edisp/dd_078167.pdf

Any consideration of water consumption or alternative water supply needs to consider the carbon embodied in the water as a result of the specific water network and consider it in making carbon transition-related decisions.

2.1 What is impacting decision-making

The implementation of district level schemes is extremely complex. The local government body controlling the area in which Broadway is situated, the City of Sydney, has faced many real and perceived constraints. (Coutard, 2014)outlines that urban residents are affected by flows and exchanges of energy and water related events far beyond their immediate district. Marrying the competing priorities of local networks within the wider National Energy Market (NEM) or Sydney Water networks is difficult. There are also profound changes in the wider market due to the rise of renewable energy, distributed energy generation, local supply and new technologies which are driving a complete transformation of the existing economic and technical structure of both energy and water markets.

There are many other constraints on decision-making including the lack of available capital, the difficulty measuring existing environmental impacts, political uncertainty around pricing carbon (or other related schemes), technical challenges, (such as how to connect various buildings in a cost effective manner), and how to integrate technologies.

There is often a lack of appropriate knowledge and varying levels of social engagement in the change or transitions involved in district energy systems. In addition the multitude of stakeholders who have to be pro-actively engaged is high. In other words, we cannot assume that individuals and organisations will simply accept the need for change: they must indeed act in a multi-lateral manner for change to take place. (Coutard, 2014) posits that the key to successful transitions is an understanding of the shifting positions and practices of different actors or stakeholders.

Districts change over time, new buildings emerge and old buildings are decommissioned. Within each building there is also equipment at various stages of lifecycle. This means that district wide change impacts on each building in different ways. There are also spatial constraints such as where to locate energy centres and how to find room within existing buildings.

The main regulatory barriers exist in in relation to accessing the electricity distribution networks as well as recognising the environmental benefits of district schemes in common building rating tools such as NABERS. Shared infrastructure also creates difficulty in energy and water procurement decision-making insofar as question of who appoints such a stakeholder and how should they operate emerges.

Underlying all of these factors are the human values that are driving decisions around lower carbon outcomes. As outlined in (Miller, 2013), we must define what it means to implement a “just” energy transformation that will neither” perpetuate the existing negative impacts of energy production and use nor create new ones”. Specifically (Rutherford, 2010) identifies challenges caused by the competing views of sustainability and how to articulate and prioritise policies relating to energy transitions.

Third-line forcing regulatory impediments in competition law to thermal energy sharing also impedes decision making in Australia. Under Section 47 of the Competition and Consumer Act 2010, it is prohibited to require, as a condition of supply for good or services, that a party enters into a separate commitment with a third party. The Act prohibits such exclusive dealing, even if the latter does not have any adverse effects on competition. This is pertinent because arrangements between the owner(s) of precinct infrastructure and a single service provider may be captured by the Act. For example, to ensure demand for heating and cooling, there were plans at Green Square Town Centre, to require all residential and non-residential buildings to connect to a single local provider (Jones, 2014).

The pricing of carbon abatement has the ability to stimulate investment in low carbon precincts. Many governments incentivise the reduction of carbon emissions through carbon credits or tradable certificate schemes. In Australia, the methods used by the federal and state governments have changed over the past decade. Currently, technology-specific applications can accrue credits, for example via street or commercial lighting upgrades through schemes such as the NSW Energy Saving Scheme (ESS) or Victorian Energy Efficiency Target (VEET) scheme. The Federal government's Emissions Reduction Fund also provides additional methods for obtaining financial credits for reducing carbon emissions. However, there is no methodology designed to support precinct-wide savings. Owners currently need to apply for credits via individual component claims e.g. emissions savings as a result of a new central energy plant using tri-generation. It is noted however, that if the carbon benefit of any project is tracked, recorded, verified and sold to another party and later extinguished/surrendered by them, then the project itself cannot claim to have reduced any emissions. This is because, to claim the benefit, the project must hold the credit locally and surrender it directly to ensure it is not transferred (and claimed) by another party. Many energy utilities (scheme participants) are required to achieve government-mandated abatement targets each year and, when not achieved in-house, they must purchase them from other projects or from the carbon credits market. Such credits can however incentivise precinct or building level projects depending on whether the emissions reduction goals are local or global.

The value of carbon credits such as renewable energy certificates (RECs) are related to the carbon emissions intensity of energy generation. In Australia, most state grid electricity relies heavily on coal-fired power stations and has a relatively high carbon emissions intensity. Over time, as power stations become cleaner, intensity reduces. Consequently, carbon credit prices for alternative cleaner or renewable energy generation is likely to fall over the long run. However, the financial return on investment for low carbon precinct solutions is impacted by many more variables than merely the applicable carbon credit price. For example, these factors might include the

- Price of and overall demand for grid electricity,
- Savings from the consolidation of equipment and service contracts, and
- Savings from economies of scale.

Estimates in 2013 (prior to new ACT and Adelaide carbon neutral commitments) The trends for emissions intensity by state are show in Figure 5, for a scenario that assumes carbon pricing policies are maintained. Future trends are likely to be lower than these estimates due to recent state government announcements. Tasmania's emissions have always been historically low due to its ability to utilize hydropower. Future trends will also be lower because of new state government commitments.

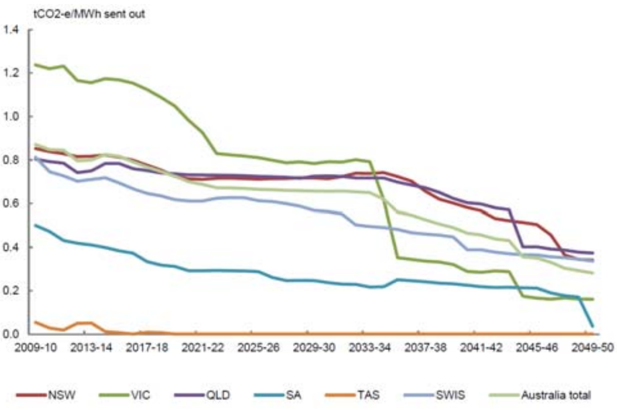


Figure 5 Emission intensity by state in Australia (source)

The City of Adelaide and Australia Capital Territory (ACT) are aiming to switch to 100% renewable energy by 2025 and, as a result thereof, there will be little incentive for a precinct to move to a decentralised energy solution (internal network) for emissions saving reasons. In other words, energy efficiency and economies of scale benefits would still deliver financial and other efficiency benefits but would not contribute to the overall carbon neutrality (zero emission) of the electricity grid. As precinct solutions often can take 3-5 years to implement and rely on long-term 15-25 year agreements between parties, they are unlikely to be attractive to owners unless there are significant financial savings *per se*. That is, the carbon benefits of such as system will reduce over time and be negated by cleaner generation improvements in the electricity network. If other states and territories in Australia follow this policy lead then the same condition will apply Australia-wide.

2.2 Sustainable Vision for Precincts

The vision for sustainable, low carbon precincts cities encompasses a radical transformation of the urban form occurring over the next twenty-five years. This transformation is driven by a recognition that we need to live within planetary boundaries and that with a rapidly growing population, highly efficient and sustainable cities will drive economic growth, well-being and liveability. Developments in resources management, use and supply technologies and systems - ranging from energy technologies such as solar cell applications, electric vehicles, as well as information and communication technologies leading to online connectivity through apps and social media- and developments in robotics will be the foundation for the future. Together with changing relationships between individuals, communities, businesses and government towards virtual workplaces, pedestrian and cycling mobility, sharing economies and living buildings.

In this envisioned future, buildings may interact and adapt to their local environment and occupant needs enabled by in-built smart technology that provides real-time data on resource use, consumption and movement of people. This is tracked, monitored and managed through immediate feedback loops enabled by multiple forms of media and personal devices. These will be connected to larger networks, such as the electricity grid and centralized water infrastructure, to interact and help manage resources demand and supply through daily and seasonal peaks and troughs. Building infrastructure will not only be smarter, but 'living' through application of biomimicry design in building facades such as bioreactors, energy generation and living walls and roofs.

Cities will require new infrastructure to meet growing population demand and urbanization, and will also require significant retrofits of existing neighbourhoods and public areas. Community coalitions will be able to engage with and manage local and distributed forms of service delivery that interact with the existing centralised infrastructure, thus providing flexibility and resilience for the city.

The business models underpinning these interactions may be based on shared models, which identify nodes and precincts within the city as opportunities for shared infrastructure to maximize efficiency of space, delivery of services and costs to consumers. Partnerships across multiple stakeholders – developers, community, government and local businesses – will seek to find the best outcome to enhance neighbourhoods, liveability, sustainability and vibrant economic health.

In this future scenario, innovation in sustainable infrastructure and business is stimulated by supportive government policies and programs that go beyond target-setting and prescribing desired outcomes and encourage incorporation of principles of restoration, regeneration and resilience into decisions across the utilities services value chain. This approach moves beyond designing for low carbon and looks at systemic enablers, emergent technologies and business models in the energy and water sector that drive a step change in how these services are configured and consumed.

We acknowledge that there are many factors – local, national and international events, geo-political actions, economic, cultural and climate-related - that will affect how the future emerges. However, given the right combination of factors and consideration of current trends, the above vision is of both a plausible, and essentially preferable, future (Gidley et al. 2004).

There are a number of uncertainties that are likely to have significant impact on the shape of the transformation occurring in city energy and water systems over time, including the influence of fuel prices, carbon and energy policies and their specific targets and mechanisms, changes in the costs of technologies, and the nature of change in urban development environment. Each of these variables is driven by a range of unique factors and contexts, and environmental factors.

As energy and water infrastructure is replaced over the course of many decades, and fundamental infrastructure architecture over centuries, decarbonisation and resources scarcity, and an unprecedented rate of change (particularly in the energy industry) is driving the need for bold decisions to be made in the next decade so that we can continue to supply and use these key resources sustainably in the future. These decisions also directly influence which technologies, business models or operational systems will succeed.

Within this context, the premise of this project is to facilitate moves towards a more sustainable and resilient precinct design and infrastructure planning by providing information and supporting and nurturing collective action and dialogue on the complex issues we face.

2.3 Physical Attributes of Precincts

The physical attributes of a precinct include climate, density, resources usage patterns, proximity to alternative resources (including waste heat and passive cooling) and existing assets. These attributes will affect the viability of district energy and water saving projects. In particular, alternative energy and water supply projects commonly utilise locally available resources or take advantage of synergies with local industries, utilising waste or spare capacity already available in the neighbourhood. In contrast, predominantly demand reduction led projects, use either additional control systems to optimise performance of existing equipment or building management systems, or remodel the bulk delivery of deep building retrofit on the precinct scale.

The Table below summarises cases that reflect a range of precincts with different physical attributes. The table also includes examples of how technology has leveraged the physical attributes of each precinct. .

Table 2 Physical and Technical Summary of Low Carbon Precincts

Case	Technology	Climate Av T oC	Density/ Building Typology	"Free" Resource(s)	Benefits	Refs
South East False Creek Neighbourhood Energy Utility, Vancouver	Draws low-grade heat from the sewer system, and uses centralized heat pumps to provide high-grade heat to customers	9.9	32 ha 560,000 m^2 Mixed, 90% residential 15,000 residents	Waste Heat Recovered from the Sewerage System	50-65% CO^2e reduction from BAU	Berry 2010)
Dockside Green Energy	Waste wood is gasified into syngas and used in a combined heat and power plant	9.9	6ha 120,000 m^2 Mixed use 2,500 pop	Waste heat recovery being investigated for future phases	Carbon neutral - including energy generated for on-site and off-site use. 50-60% energy savings.	Dockside Green Energy, 2015; EcoDistricts, 2015)
Paris Cooling Network	Electric Cooling (6 plants - 215MW) Cool storage Additional cooling by River Seine	11.6	500 Buildings in the CBD		65% reduction in water use, 50% reduction in emissions 35% drop in electricity used	Di Cassa, Benassis, & Poeuf, 2011; GDF SUEZ, 2010
Paris 36 Geothermal District Heating Networks	Geothermal	11.6	Various	Geothermal		(City of Sydney, 2013a, 2013b)
Portland Brewery Blocks	Electric chillers	12	Original 5 block redevelopment with two external customers	None		(Portland Sustainability Institute, 2011b)
New York State's Cornell University	Lake cooling system	12.6	Low-medium density campus	Lake Cooling	saves 80% of the electricity used for cooling	(McGowan, 2010)
Barcelona Innovation District 22 - Heating and Cooling Network	2 x 4.5 MW absorption chillers 4 x 5 MW heating condensers 5 m^3 cold water storage tank	15.3	60 Large buildings incl. hospitals universities and manufacturing 13 km pipework	Waste heat from municipal solid waste incineration. Chilling capacity is boosted	53% reduction in fossil fuel use	(Peters, Serrano, & Andreu, 2011)

Case	Technology	Climate Av T oC	Density/ Building Typology	"Free" Resource(s)	Benefits	Refs
				by sea water cooling		
Dandenong **Melbourne** **PENDING**	Gas turbine with adsorption chillers	15.5	7 ha Mixed 4000 homes 5000 jobs	None	60% carbon reduction compared to grid	Cogent Energy, 2015
Ripongi Hills District Heating and Cooling, Tokyo	6 X 6.3 MW Turbines – gas fired or distillate Steam absorption chillers with recovery boilers	15.6	Mixed commercial, residential, hotel, TV station – 24 hr demand	None	Economic	Clinch, 2012
Century City and Los Angeles heating and cooling networks	Combination of trigeneration and electric chillers	17.2	1.1 million m^2 commercial customers in the CBD	None	Economic, Space saving	Veolla, 2015
Brisbane	Cold water storage Electric Chillers	20.6	Commercial customers in the CBD	None	10-30% energy savings for individual buildings 24,000 CO_2t/yr	Citysmart. 2016
Honolulu	Deep Sea Water cooled with electric chillers	25.1	9 commercial customers in the CBD including banks, education and medical facilities	Sea Water Cooling	84,000 CO_2 t	Honolulu Seawater Air Conditioning, 2016; McGowan, 2010

2.3.1 Climate

Often, climate sets the key design parameters for power generation and water recycling schemes. Cogeneration schemes have been used to generate electricity and hot water in colder climates, such as in Denmark, Norway and Sweden, however, with the development of adsorption chillers are increasingly being used in warmer climates, such as Spain and Japan. An analysis of each case study's climate revealed that Sydney had similar heating and cooling needs to Tokyo, Shanghai and Los Angeles.

The impact of climate also has a temporal aspect. District cooling will become significant as the world's temperatures increase in the future due to climate change. Major growth is predicted in developing countries as a greater percentage of the population move to cities and living standards improve. District cooling systems not only reduce overall and peak summer electricity demand but also reduce leakage of ozone depleting HCFC refrigerants (UNEP, 2014).

2.3.2 Density

Density is generally positively correlated with viability of district energy schemes (United Nations Environment Program et al., 2015), however, density does limit the ability of roof top solar PV, solar thermal and rainwater tanks to contribute to a significant proportion of existing water and energy usage. For example, a recent solar energy analysis of the Lloyd EcoDistrict, completed by the National Renewable Energy Lab, estimated that 2% of annual energy demand could be satisfied through on-site solar PV installations. Although the contribution of solar PV to energy use in the high density environment is limited currently, this may change as Building Integrated Solar PV becomes cheaper in the future. Application to westerly facing facades has the potential to significantly reduce peak grid energy usage in countries where this occurs in the summer months. Cases studied also suggested that geothermal energy extraction is more commonly applied to medium to low density campuses although Paris is a good example of geothermal energy being utilised in the central business district.

2.3.3 Usage and diversity of demand

Usage patterns can influence the viability of energy and water reduction projects. For alternative supply projects in particular, decentralised precinct infrastructure commonly develops from a plant serving a large anchor load such as a hospital, university or a group of multi-residential buildings. Typically, a variety of users - including residential, commercial and retail - will smooth the precinct demand profile, as resources usage of retail and commercial premises is much higher during the day whereas peak water and energy demand occurs before and after business hours for residents. This increases the number of operating hours of district infrastructure, improving scheme viability. In Tokyo's Ripongi Hills district heating and cooling scheme, the building mix provides 24-hour demand. Customers included retail, commercial and residential customers including a large hotel and a TV Station.

Diversity of demand can also assist in water balance for recycled water. For example, a mix of residential users that produce large amounts of recycled water, with municipal users, who can off-take large amounts of recycled water for irrigation.

A changing demand profile in the high density environment will change the viability of district schemes in the future. Changing building uses and hours of operation, changing work practices like tele-commuting and hot desking plus increasing on-line commerce will constantly change water and energy usage patterns meaning that a larger customer base may be needed to ameliorate these changes.

2.3.4 "Free" resources

Many district energy systems take advantage of "free" resources, most notably heat from municipal waste incineration facilities which is a high energy waste stream. Barcelona utilises steam generated from waste heat from a Municipal Solid Waste incineration facility to run absorption chillers for its district heating and cooling scheme. Chilling capacity is also boosted by cooling from sea water resulting in high yields without the use of cooling towers, thereby reducing water use (Peters et al., 2011).

Other large scale free cooling projects include Enwave's, Deep Lake Water Cooling Scheme which utilises Lake Ontario as its cooling source. Environmental benefits of the project have been summarised as:

- Reduction in electricity usage by 90% compared to conventional cooling,
- Reduction greenhouse gases emissions by 50%,
- Removal of 145 tonnes of nitrogen oxide and 318 tonnes of sulphur dioxide from the atmosphere relative to the use of coal-fired electricity, and
- Saving about 714 million litres of fresh potable drinking water compared to separate cooling systems (Cannadian Urban Institute, Canadian District Energy Association, & Toronto Atmospheric Fund, 2008).

In Sydney, there are many examples of harbour cooling designed to supply single buildings such as the Sydney Opera House, Star City Casino, AMP Cove, Woolloomooloo Wharf, King Street Wharf and the Sydney Harbour Convention Centre (McGowan, 2010). The Barangaroo development is the latest addition to this list. Most of these systems are open loop systems; the sea water is used directly in the condenser. While these systems have the advantage of having a lower capital cost to install, they have higher running costs because system components are required to be corrosion resistant. They also have higher impact on the marine environment as anti-fowling chemicals are discharged directly into the receiving water. The alternative is the closed loop system which has an even higher capital cost, but lower running costs. In 2010, it was reported that both systems are more expensive than traditional cooling towers in Sydney, in contrast to larger district schemes, such as Toronto and Honolulu which are economically viable (McGowan, 2010).

More recently, experimentation with utilisation of lower energy heat waste streams from data centres and sewage systems has been explored. For example, False Creek Neighbourhood Energy Centre provides space heating and hot water to new buildings at the Vancouver Olympic Village neighbourhood through sewer heat recovery - Vancouver's South East False Creek Neighbourhood Energy Utility extracts waste heat from sewage to provide 70% of their annual heating needs and reducing carbon emissions by 50%. Energy price is within 10% of normal value. (vancouver.ca/home-propertydevelopment/neighbourhood-energy-utility.aspx).

No examples exist of waste heat utilised by absorption chillers to produce district cooling to date, although evidence exists that a data centre could use its own waste heat to drive a heat-activated lithium bromide absorption chiller, to partially offset its own cooling needs (Haywood, Sherbeck, Phelan, Varsamopoulos, & Gupta, 2012)

Box 1 – Paris District Cooling Network

The district cooling network in Paris uses electric chillers to deliver cooling to 500 commercial buildings in the central city. First developed in 1978, the district cooling network has been operating through a concession model since 1991 from the City of Paris. This effectively provides the operator (Climatespace) with the physical access needed to operate the energy network and the right to charge for it, with limits applied. The "central" district cooling of the city of Paris includes today six cross linked cool generation plants with a total cooling capacity of 215 MW, with an additional 140 MWh/day cooling generation capacity from different storage units installed on three sites. The cool storage systems coupled to the district cooling network in Paris optimise the plants operation and allow for more flexibility. About 90% of the stored energy is generated by chillers refrigerated by the Seine river water (Di Cassa et al., 2011). Peak power demand is reduced significantly due to cool storage. Energy is consumed at night time when electricity prices are lowest and cooling is more efficient at lower temperatures. Storage also makes the system more resilient to short term power outages. Savings from the reduction in installed power compensated for the overinvestment necessary for the thermal storage system.

Benefits quoted by the operators include a 65% reduction in water use, 50% reduction in greenhouse gases emissions and a 35% drop in electricity used. Note that the greenhouse gases reduction was attributed to the reduction in refrigerant emissions, the overall reduction in electrical consumption and shifting electricity use to night time hours when base load is predominantly supplied by nuclear power. Application to the Broadway context would not yield the later saving because off-peak load is supplied by coal power stations in NSW.

2.3.5 Project Synergies

The viability of some larger schemes is related to synergies gained with other projects. For example, Enwave developed its deep water cooling plant in Toronto because the project was mutually beneficial to Toronto's water utility. Toronto Water needed new pipes to extract water from Lake Ontario. Enwave payed to co-locate its network with Toronto Water's drinking water pipeline, using the drinking water system to adsorb waste heat. Water from the lake is pumped to Enwave to provide cooling to a closed loop cooling network. The Lake water is then used as Toronto's potable water supply. In 2008, the system could provide the equivalent of 75,000 tons of refrigeration (263 MW). There is no additional extraction of water from the Lake, hence Enwave did not have to pay significant water extraction license fees.

Costly district energy piping infrastructure under city streets makes district energy systems more conducive in situations where other street enhancements (such as greening and light rail installation) are being implemented so that the significant cost of road construction can be spread over multiple projects (Overdevest, 2011).

2.3.6 Legacy assets and timing

In existing precincts, legacy assets will significantly impact the viability of projects that seek to lower carbon emissions. For example, the City of Sydney Tri-generation Master Plan suggested a heating network for Sydney which necessitated customers having to purchase adsorption chillers. Not only are these chillers relatively expensive, they consume significant amounts of floor space and demand moderate maintenance programs. Each organisation would have to replace their existing electric chillers, which are likely to have residual economic life. Timing of requirement to connect to the system would have been crucial to its success if it had gone ahead. In contrast a cooling network would save each organisation significant floor space and maintenance expenditure but may have been more expensive overall. The same constraints exist for recycled water networks. It is noted that this project is specifically aiming to address this through seeking to consolidate the precinct asset information to enable precinct scale decisions to be coordinated with the existing asset value cycle.

In contrast, demand reduction projects involve "smart "buildings programs i.e. they use additional control systems to optimise performance of existing equipment and building management systems. A smart buildings program is not however equivalent to ICT deployment. It also includes the optimisation of "intangible assets" like human capital in the organisation. The smart buildings pilot for Seattle's commercial business district is a good example of the smart buildings philosophy applied to the district scale. District 2030 Seattle, Seattle's utility Seattle City Light, Microsoft and Accenture Smart Building and Energy Solutions have collaborated to deliver the program. The cloud solution will collect building data and use data analytics to improve building control and prioritise building alarms and work flow practices to improve energy efficiency. Combined energy and maintenance savings are predicted to be between 10 and 25 % (Mitchel, 2013). This approach could be applied to a precinct which incorporates a district heating or cooling scheme.

Box 2 - Microsoft Smart Building Program

Companies like Siemens and Honeywell have been dominating the smart building industry for many years and have been driving significant innovations in this space. More recently, companies like Microsoft are entering the smart building market. Microsoft trialled its new smart buildings platform in 2011 with its own building portfolio. The pilot phase focused on 13 out of the 40 buildings in its portfolio, representing 240,000 m^2 of floor space. The age range of buildings varied from over twenty years to almost new with multiple building management systems in place.

The new platform did not seek to replace existing BMS systems. Data was collected from equipment control panels or from the BMS servers to a middleware server which also collected contextual information, such as building type and usage. The middleware server transmits the data over the cloud to the relevant energy management application, hosted off-site which aggregates Microsoft data with third party weather data and building-level electricity consumption data provided by the utility. Analytics are run by the building energy management application, applying algorithms to optimise building control, identify faults and prioritises action. The newly established operations centre notified engineers via an interactive web interface which could be accessible via mobile devices.

The new platform achieves energy reductions in three ways:

- Enhanced fault detection,
- User friendly alarm management,
- Continuous commissioning and predictive operation.

Microsoft found that the new building analytics revealed faults that otherwise would have gone un-detected. The new building analytics not only identify building faults, but quantify waste in terms of dollars per year. Hence faults across a building portfolio can be prioritised and building managers deal with the most expensive problems first. This contrasts to common practice where BMS systems produce hundreds of error messages per day and operators have to select the most important one. This inevitably leads to errors; potentially wasting time on false alarms or minor issues that do not waste significant resources.

The new building analytics can analyse thousands of alerts systematically to detect patterns over time allowing set points to be tuned, wasteful equipment to be identified and schedules and routines to be optimised. This “continuous commissioning” process is thought to save Microsoft $1million/yr. Usually this optimisation process would only be performed every 5 years, wasting energy as system performance falls from the commissioning date. Microsoft reported that from a capital investment that equated to 10% of the annual energy usage, a 2 year pay back in investment was received. Energy reduction varied from 10-25% across the building stock investigated.

In addition to technical performance, the following behavioural lessons were learnt :

- Avoid disruptive change - New tools come with a learning curve requiring training and expectation management. Avoiding BMS replacement was positive as was an extensive pilot and training program,
- Engage the organisation in behaviour change. Actions such as internally reporting consumption per employee over organisational departments was found to be positive,
- Building engineers often lack the time to familiarize themselves with new analytics tools, and make use of them in their daily routine. Microsoft introduced an operations centre with additional staff given the job of monitoring alarms and dispatching jobs to building engineers.

In the future more predictive operation may be possible. By monitoring security access information, laptops connecting to the server or mobile phones in range as a proxy for the number of employees present, the HVAC systems could be automatically adjusted to account for increased or decreased conditioning requirements. Predictive algorithms could also be used for further energy savings by optimising off peak cooling and heating with energy pricing changes. This sort of technology could be used to manage a precinct micro grid where thermal energy and electricity could be used, stored (using electric car batteries, on-site batteries, ice storage etc.), traded with neighbours or sold back to the grid depending on price changes. Grids could also be designed with flexibility to cope in emergency power outages.

2.4 Stakeholders

There is a large amount of literature that promotes the benefit of stakeholder engagement. While there is literature focused on stakeholder engagement in transitioning precincts, such a transition to lower carbon energy and water infrastructure presents a significant change management exercise. Stakeholder engagement can improve scientific credibility, policy relevance, and legitimacy of assessments, allow for the generation of novel policy solutions, reduce opportunism, address distrust, and increased learning and empowerment of citizens. (UNSW, 2014)

(Adams, 2014) argues that there is an inherent distrust of energy actors such as ESCO's, distribution incumbents and a tangible path dependence (i.e. existing entrenched ways of doing) which ensures that precinct actors converge on the status-quo. This could perhaps be managed through greater participation which increases perspectives and improves transparency, accountability and understanding, and reaching broader based decision-making can create conditions for improved energy policy outcomes. (Adams, 2014) also suggests that a key benefit of deeper engagement is can lead to more resilient outcomes in the long term.

(Rutherford, 2010) suggests that deliberative engagement processes can allow for a more 'co-evolutionary' understanding of how the 'social', the 'technical' and the 'environmental' are inextricably linked with behaviours and interactions between actors.

2.4.1 Who are the stakeholders in a local district

A local precinct includes a wide variety of stakeholders who have varying levels of engagement in the sustainability concept. When thinking about low carbon transitions more generally, (Coutard, 2014) suggests that this localisation makes the issues more pertinent and contextualised and offers the potential for more effective technical and policy approaches. (Coutard, 2014) believes that energy transitions are inherently political in that they are based on transforming existing institutional and governance arrangements and redefining relationships between different actors with varying amounts of power.

In a district transitions you have, on the one hand, local governments who are strategically positioning all around the world (e.g. initiatives such as c40.org and ICLEI low-carbon cities) as major drivers of energy transitions. They bring their local knowledge and proximity to users. On the other hand, you have the State and Federal governments who are often influenced by energy market incumbents who ask the practical question of how to manage the common good(O'Neill-Carrillo, 2010).

At the same time, energy stakeholders are becoming much more than passive receivers of energy produced in a remote location. (Chris Marnay, 2012) suggest that the local energy networks of today involve new paradigms . The energy stakeholders impacted include wider network customers, local grid customers, independent power producers (IPP), transmission and/or distribution network operator (DNO), utilities, technology providers, and governments (note – micro-grids are local energy grids).

An example of thestakehodlers related to microgrids is outlined in the following diagram.

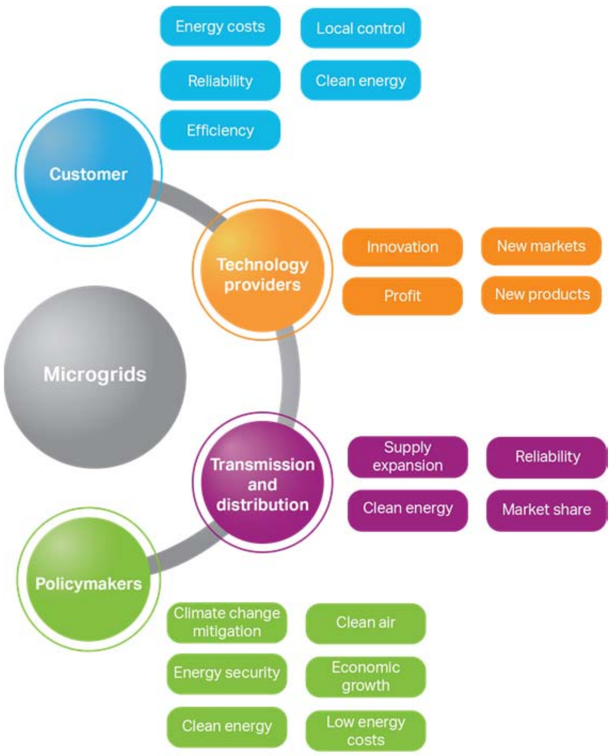


Figure 6 Microgrid Stakeholders

(Miller, 2013) provided an even broader definition of stakeholders:

"energy systems include financial networks, workforces and the schools necessary to train them, institutions for trading in energy... city neighbourhoods, and companies as well as social norms and values that assure their proper functioning, social processes that stimulate and manage energy transformation, the social changes that accompany shifts in energy technologies, and the social outcomes that flow from the organization and operation of novel energy systems"

A more detailed outline of potential stakeholder groups within an example district in Broadway, Sydney, is outlined in Appendix A.

2.4.2 Potential process for Engagement

The following table identifies a sample of approaches that have been used for energy transitions.

Table 3 Examples of engagement processes

Author	Process
(Adams, 2014)	Identification of stakeholders, establishment of baseline, scenario identification, elaboration of scenarios through expert presentations and commissioned papers, iterative discussions around this work using formal dialogue sessions, independent assessment of stakeholder trust, solicitation of submissions, presentation of recommendation to stakeholders and then presentation of recommendations to government.
(Starkl, 2009)	Generation of alternatives, formulation of objectives, reduction of criteria and alternatives, reduction of uncertainties, then assessment and decision
(Nevens, 2013)	Setting the stage, problem identification, visioning, back-casting, experimentation, translating and monitoring & evaluation.

The key processes that are relevant to this report on engagement strategies are stakeholder identification, establishment of a baseline and generation of scenarios.

2.4.3 Stakeholder Identification

(Kern, 2008) looked at various means of selecting stakeholders. The initial strategy was to recruit from existing policy networks. Another was to use publicity. Business and NGO stakeholders were selected by the transition team. The main criticism to this type of self-organising approach is that building on existing networks leads to a stakeholder group derived from the incumbent regime. As with several authors ((O'Neill-Carrillo, 2010) , (Adams, 2014) identified that engagement of an "honest broker" was critical to the process. In the case of the Broadway transition, one initial theory in the research was that it would be most practical to implement a "transition team" (Nevens, 2013) which manages stakeholder groups within the district and guides them through engagement processes such as scenario planning.

It is also important to link this group with the existing regime and the wider landscape. To achieve this effect, a long term best-practice collaboration between industry, the government and the community should be established. The role of this is to feed critical scientific information to the transition team, and to use local findings to influence long term policy.

During the final consultation process in the City of Sydney trigeneration masterplan, several sources commented that the type of skills required to implement the plan were not available locally. This is something that can certainly be improved by a sound engagement strategy. The types of knowledge required range from: technical , operational and economic understanding of energy markets; understanding of environmental impact measurement; local knowledge around existing infrastructure, plans, customer requirements; transition management experts; governance experts; legal and regulatory experts; outreach strategy, local capacity building; long term monitoring. A good stakeholder engagement strategy will find the key resource at an appropriate time and inject them at the appropriate time in the process.

In practice this level of pre-meditated stakeholder organisation proved almost impossible during the research process, and the outcomes and some recommendations are outlined in the governance section below.

2.4.4 Establishing a baseline

The establishment of a baseline requires documentation of the current social, political, economic technical and environmental status-quo in the district.

There are many tools and processes for documenting technical and economic aspects of the current state. Critical information includes the modelling of carbon intensity, energy loads, equipment age, financial flows, stocks and flows of energy (potentially using a Sankey diagram) , and energy services requirements model.

Models that may be compatible with this exercise are Kinesis CCap or AECOM's Sustainable systems integration model (SSIM), MUTOPIA. These tools incorporate impact assessment techniques (such as life cycle analysis) with broader understanding of energy flows, scenarios, and resultant economic and environmental impact. These have been explored in the CRC LCL research on precinct design tools. Tools such as building information modelling, or a newer concept of District information modelling would potentially create a richer and more granular decision making platform that include both usage and operational history of equipment, as well as the spatial characteristics of buildings. Figure 7 is a screenshot of the AECOM SSIM Energy Simulator that can be used to assess energy improvement strategy options amongst other functions.

Figure 7 AECOM SSIM Model (Energy Vision Simulator)

It is potentially more difficult to map the social processes. (Roorda, 2014) suggests that documentation relevant issues would include such as persistent blockages, values and norms, relationship structures, major relevant narratives and group dynamics would be useful.

2.4.5 Generation of scenarios

The generation of alternatives or scenario planning is a very common process in mapping energy futures. These alternatives often start at a "landscape" level and then must be mapped locally. An example of a landscape mapping process is Shell (Shell, 2014). Another macro scenario example is given by (Ben Elliston, 2014).

(Kei Gomi. a., 2010) explored a scenario creation method for a local scale and demonstrated that it is critical to create descriptive scenarios, quantify socio-economic assumptions, analyse various low-carbon counter measures and then look at impacts of various policy settings. (Phdungslip, 2009) used a decision support tool named Long-range energy alternatives planning (LEAP) to simulate a range of policy interventions. LEAP used multi-criteria decision making (MCDM) framework and Web-HIPRE which is an on-line multi-attribute theory tool. After modelling, policy settings were developed and then checked for practicality.

2.4.6 Discussion of potential engagement strategy – transition theory, futures frameworks

In a recent article on the district energy transitions (Hilson, 2014), the multi-level perspective on transitions was identified as a framework for identifying and managing a transition to a low carbon district. Within this theory stakeholders are broadly described as: a "transition team" (Nevens, 2013) who enact the transition; the regime , which includes existing energy market structures, existing regulatory frameworks, and any other incumbent stakeholder structure that re-enforces the current path; and niche experiments, which represent activities that aim to disrupt the regime and send it on an alternative path.

Within this group, the stakeholder dynamic is likely to involve trying to harness the energy of the transition team along with expert driven information gathering and successful niche experiments to influence the regime actors to implement new policies, fund initiatives and smooth the way for change.

Although this is potentially a good start to engagement, it is fairly high level and other environmental decision making tools will be required to ensure a successful engagement process. The processes above describe how stakeholders could be identified and then how a baseline may be created and scenarios developed. It is also clear that a variety of tools can be deployed for options analysis (such as multi-criteria analysis and computer aided decision support).

The appropriate process for this transition would potentially be similar to that described above by (Adams, 2014) and involve the co-creation of reports with input from stakeholders such as residents, students, lecturers, technology providers, consultants, building owners and building operators. The transition team would manage this information and provide facilitation by an independent third party. After several iterations the proposal could then be used to elicit support from decision makers and to influence policy makers more broadly. The community of stakeholders (many of which are described in Appendix A), would be initially informed via an expert report, and then using this base information, the stakeholders could be brought together during the visioning and scenario planning, and then for a series of meetings to review and comment on a report focusing on the transition. Interviews and surveys could be used to reflect on the effectiveness of the process and perception of independence.

A complimentary approach to engagement, based on the transition literature, is the use of niche experiments. Niche experiments are new products or processes that challenge the status-quo. In addition to technical experiments (Bulkeley, 2013) identifies that demonstration projects, best practices, novel policy instruments, new forms of public–private partnerships, community-based initiatives can all be an important way to engage the community in a low carbon transition.

The nature of this decision, as discussed above, is based on an environment of constant flux, with high degrees of uncertainty and many constraints. As such, an adaptive management approach would be suitable (Allen C. F., 2011). Adaptive management would require strong monitoring and a process of continual learning. Outcomes of this type of process do not, in a local sense, create huge risks and as such a risk based approach is not going to be effective.

Daniel Hilson of Flow Systems proposes that a more localised strategy with a higher level of engagement would have significant benefits for transitioning precincts. Drawing from earlier research (Hilson, 2014), a transition management framework is recommended and a process which articulates an adaptive management approach drawing on a broad stakeholder group in a deliberative environment. This group would work with a transition team, along with experts to co-create a report that could then be used to inform and influence policy makers.

The goal of this approach would be to establish a process that was seen as independent and reflective of the values and needs of affected stakeholders. An adaptive process implemented across a broad stakeholder group over a longer time scale would create a resilient platform for change and support the wider goal of a lower carbon city.

Historically we tend to be able to forecast accurately short-term scenarios into the future, while more and more uncertainty exists as we extend the timeframe. Looking out to 2040, therefore, means that a multitude of possible futures may eventuate influenced and shaped by choices and decisions made by multiple stakeholders at every point along the timeline, together culminating in particular events, developments, policies, innovations and cultural practices. These are influenced by larger-scale events and changes as well as less controllable factors such as emerging forces and unforeseen events that can disrupt our social, environmental and economic systems. Projecting forward is therefore fraught with complexity.

Given the future focus of this work, futures literature may also provide a useful framework. To give a sense of the certainty associated with any particular future emerging Figure 8 represents the (un)certainty associated with given futures over time. These are described as probable, plausible and possible futures (decreasing in certainty as you move away from the centre) (Voros' 2003).

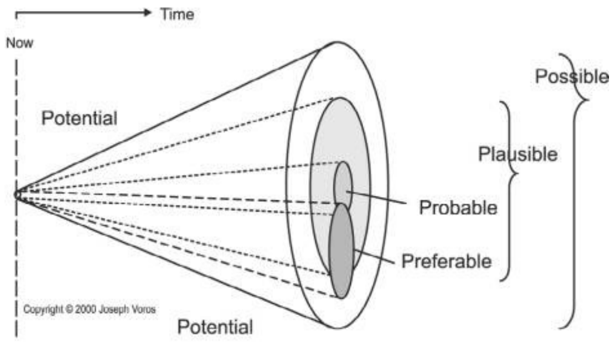


Figure 8 The Futures Cone: Probable, Plausible, Possible and Preferable Futures

Source: Voros, 2003 adapted from Hancock and Bezold 1994

Differentiated from these three types of future is a *preferable* future which is typically a future scenario generated by a particular group or individuals. For this research project, the preferred future vision has been pragmatically informed by the boundaries of the Empowering Broadway project vision and mission to:

- Create a framework for stakeholders to transition existing precincts to achieve low carbon energy and low carbon water solutions,
- Identify and understand the economic, stakeholder, regulatory and technical barriers to transitioning existing communities to low carbon energy and water solutions and devise viable pathways for stakeholders to successfully transition.

In setting the context it is useful to understand that a transition is a type of systemic change occurring over long timeframes. Change will happen regardless, so this typology can help think through the type of change that is desired or to be prepared for. Disruptive and shock forms of change can have particularly negative consequences over short periods of time.

This also requires an understanding of not only trends based on past data, but understanding emerging and weak signals which may signify currently occurring shifts that will change future possibilities (e.g. energy networks assuming continual growth in demand are now facing possible stranded assets by not recognising changes in behaviours and technologies impacting on both supply and demand)

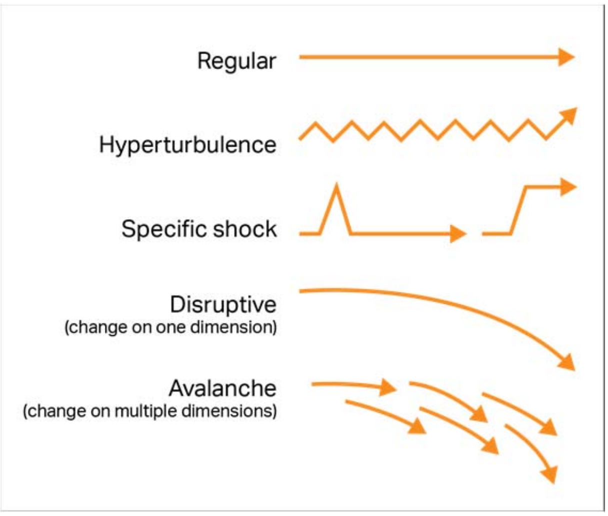


Figure 9 Typology of Transitions (Geels and Schot, 2007 adapted from Suarez and Oliva, 2005)0000

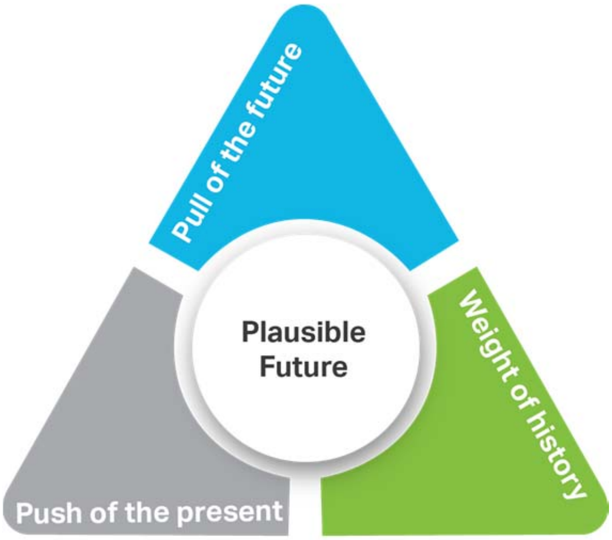


Figure 10 The futures triangle

In workshops and stakeholder interviews, the futures triangle acts as a structuring tool to help participants think systematically about the issues that shape the future of the Precinct. It is essentially an environmental scanning tool, for noticing what issues shape the future.

Visioning and scenario planning processes can be used to draw out distinct options for the future with stakeholders. Where the futures triangle helps to map possible futures, visioning processes help to identify preferred or desirable futures.

Table 4 Transition action and research questions based on TM framework and integrating futures methods

TMC Phase	Aims	Tasks	Related Research Questions	Possible Research Methods (adapted from (Inayatullah, 2008)
1	Problem structuring, establishment of the transition arena and envisioning	• Map the issues • Set the system boundaries of investigation • Identify and map stakeholders • Generate shared vision	• What change agents will commit to leadership on this issue? • What are the boundaries of the system we seek to transition? What and who or what constitutes the Landscape, Regime and Niche-innovation levels? • What is a picture of the system in terms of patterns of change? What changes have occurred? What enablers and challenges for transitioning to a low carbon economy exist within the established boundaries? • Who are the stakeholders that will be involved and/or affected by this transition? • What is the type of change sought and/or avoided? Regular? Disruptive? Shocks etc. Total transformation or technological substitution in certain industries? What are the emerging issues and weak signals that signify change in a certain direction? • What is the precinct stakeholders' guiding vision? • Who is not being represented in the process of establishing this vision/whose voice is dominant?	• Stakeholder and systems mapping • Shared history, Futures Triangle or Futures Landscape • Environmental Scanning, Emerging Issues Analysis, Weak Signal Analysis • Futures Wheel • Causal Layered Analysis • MLP • Guided Visioning
2	Developing images coalitions and transition agendas	• Clearly establish the transition agenda in networks • Coordinate stakeholders into generating shared future direction and strategic action plans • Identify key actors in the process	• How will this vision be achieved? • What are the changes across the categories of social, technological, environmental, economic and political /governance that will be required and when? • Who are the actors that need to be mobilized to achieve these changes? • What are key leverage points that are a must for improvements to be achieved?	• Deliberative engagement processes • Scenario development • Creative processes to developing scenarios e.g. Scenario Art • Backcasting
3	Mobilising actors and executing projects and experiments	• Collaboratively design appropriate scale projects/experime nts to facilitate the desired vision • (These may be at social, technical, economic, political or	• How can the broad category strategies by actioned by sub-sectors? • What networks need to be established or strengthened for this purpose? • What information is missing? • What support mechanisms such as government policy, incentives or funding need to be put in place?	• Deliberative engagement processes • Strategic planning connected to governance models

TMC Phase	Aims	Tasks	Related Research Questions	Possible Research Methods (adapted from (Inayatullah, 2008)
		environmental focus drawing from the range of stakeholders from business, civil society, industry, government)	• What institutional factors may accelerate or form barriers to a low carbon precinct being realized? • How could values, supportive of sustainability, be incorporated into the process?	
4	Monitoring, evaluation and learning	• Each project, as part of a broader vision to incorporate program logic or other evaluation frameworks, which can be evaluated at regular intervals, outcomes fed back to stakeholders and revisioning of process, strategies and aims as required.	• What lessons are being learnt through each of these processes and experiments at the individual level • What are the different actors telling us is working and not working? • What changes have occurred in the system and is this moving towards the envisioned future? What needs to shift course? • How can we share what we are learning with others? • At what points can learning be reflected on and fed back into the processes of change at different levels?	• Iterative and Shared Learning approach • M&E tools including Program Logic Evaluation • Reflective processes • Anticipatory Action Learning (Inayatullah, 2006)

2.4.7 Lessons from case studies

A number of global case studies were completed as part of this research to determine precinct relevant technologies and governance models used globally to transition existing precincts. The full case studies are in the Appendix of this report. Lessons learnt from the cases studied regarding precinct transitions are summarised in the table below.Edis est, ommodi que offic tet prepeli tatquia quature cumqui

Table 5 Summary of Case Studies

	Precinct Description	Precinct Technologies Considered	Governance	Implications for precinct transitions
Lloyd Ecodistricts, Portland, Oregon 162 ha	Predominantely commercial urban renewal area, includes a shopping mall, event spaces, high- and low-rise commercial office buildings, surface parking and open parkland.	Bulk lighting retrofit Bulk PV panel purchase or contract District heating – gas driven cogeneration plant	Collective governance with separate management and implementation teams. Collective goal setting, planning, financing and implementation.	Pooled financial resources Collective approach makes impact quite slowly, however confidence in the process means that stakeholders are committed for the longer term
Seattle 2030Districts Seattle CBD No a set boundary to precinct	133 commercial buildings with 4.2 million m^2 floor space in 2015	Building Management software and training Predominantly lighting and HVAC retrofit Smart building trial with selected members	Membership model where members get free services (funded by the EPA) and share their data with 2030Districts	Membership model progresses demand reduction quickly however no structures in place to progress district infrastructure
Dockside Green Inner Harbour, Victoria, British Columbia, Canada 61ha	New sustainable development on contaminated harbour front land with carbon positive ambitions. Mixed use including 73% residential, commercial and open space. 26 buildings with 120,000 m^2, floor space	MBR to recycle sewer and storm water for domestic use and water feature. Gas boiler fuelled by syngas produced onsite with local wood waste Best practice energy efficiency features	Developer fined if buildings did not receive LEED as built accreditation Water treatment plant is managed by the strata corporation and operated by private utility Thermal plant and networked owned and operated by joint venture	Although sustainable technology is built, governance and cost barriers dis-incentivise sustainable operation. Performance outcomes are largely unknown.

From a transitions perspective, the cases illustrate the key precinct scale transition pathways that are likely to be influential at Broadway, that is, the uptake of new developments, changes in energy management practices of existing organisations, the impact of local government planning processes and new ways of trading electricity across the property boundary.

Dockside Green is an exemplar sustainability development, however it is also typical of the way original sustainability goals are eroded during precinct operation. Despite the embedded district heating technology being able to yield the desired performance, economic issues often prevent the continued operation and body corporates have few incentives (or contractual obligations) to keep equipment running. In essence developers gain development concessions from low carbon infrastructure but are not held accountable for their performance. More research is needed across the sector to understand the various barriers and the corresponding policy mechanisms required to address the gap between design and performance.

Collaborative precinct programs such as Ecodistricts and 2030 districts have enabled gains in building performance by improving building energy management skills and promoting energy efficiency retrofits. 2030 districts, in particular, have produced a highly influential training package funded by the US EPA, giving industry confidence in its content. By connecting energy efficiency service providers to building operators, 2030 districts has facilitated energy savings. Smart building service providers (such as Microsoft and Accenture) are currently experimenting in the precinct, which has the potential to yield significant energy reductions in the future. Key to 2030District’s success was the data sharing protocol which allowed comparison of buildings of a similar type.

As yet, the collaborative processes mentioned above have not directly caused district scale energy infrastructure to be built. While this is not 2030District’s area of focus, Ecodistricts have spent considerable time promoting its benefits and several district energy schemes have been investigated in Portland. Ecodistricts has, however, produced important knowledge, based on case study analysis that has influenced government, (local government in particular). There is good evidence that these documents are having an impact on local government policy, however change is a slow process, sometimes spanning decades. It is therefore crucial to have trusted organisations, like Ecodistricts, that have long funding cycles so that policy impact can evolve over considerable time.

While it is clear that district infrastructure requires local government support, local government planning alone may not be sufficient to enable change. While the City of Sydney’s Master Plans were an international exemplar, the implementation process for distributed infrastructure was challenging. The City attempted the roll out of distributed infrastructure rather than experimentation to convince stakeholders of its benefits. The plans called for a major social transition, which, by their nature, take considerable time to evolve and elicit support from critical stakeholders.

A more recent and slightly differing approach is the NY Community Micro grid Competition, which is a process to identify transition experiments – communities where micro grids are beneficial in today’s context. The process is supported by state government funding, utility operators, the energy services sector and the community. Contextual factors, such as the impact of Hurricane Sandy, have also had a major influence on the community’s interest in micro grids. This competition has allowed the evolution of a micro grid which will now trial peer to peer sale of energy via TransActive Grid. Lessons learnt from this experiment will allow improvements to be made to the next micro grids implemented. If all goes well, social and technical knowledge will build to the point where experts agree on fundamental aspects of design and governance of micro grids and they enjoy widespread uptake in New York.

3.0 The future of energy and water technologies in precincts

There is a range of technical approaches to migrating a precinct to low carbon and water efficient infrastructure. Most of these approaches work on an incremental, building by building approach, rather than at a precinct scale. In most cases, the philosophy of use less first, before looking at other interventions, holds true for reducing carbon intensity. Within a precinct, this does usually mean working on energy efficiency measures on buildings within a particular property boundary before looking at precinct solutions. Also ClimateWorks (2013) reports that commercial building energy consumption could be reduced by between 26-30% with demand – side programs (ClimateWorks Australia 2013)

Warren Centre for Advanced Engineering 2009) and economic evaluations show that demand side energy reduction alternatives are more cost effective than supply options at the commercial building scale (ClimateWorks Australia, 2013; Warren Centre for Advanced Engineering, 2009).

In practice a lack of awareness and a time poor work place make projects difficult to implement energy efficiency programs(City of Sydney, 2013a; Fernandes et al., 2011). In addition to that, it is also difficult to quantify energy reductions and attribute them to retrofit programs rather than impacts such as climate variation or changes in usage patterns (Goldman, Hopper, & Osborn, 2005; Hirstt & Goldman, 1990; Vine, 2005). Notably, occupant behaviour alone has been shown to increase or decrease energy consumption by up to 30% in some cases(GhaffarianHoseini et al., 2013).

Once energy efficiency measures have been exhausted either practically or due to these social factors, governance and technical interventions should be applied at a precinct level.

This chapter focuses on the technical interventions. A review of low carbon systems and technologies and their potential impact into the future is intended to provide early guidance for further research and modelling applied to specific precinct context i.e.: Sydney's Broadway Precinct. The nature and scope of this project encompasses a high level scan of relevant technologies assessed against a number of key criteria rather than an exhaustive list of all current and emerging technologies quantitatively modelled to create a forecast out to 2040. In evaluating a future vision for which to consider these technologies, the uncertainty associated with any form of prediction should be recognised.

3.1 Technology Review Method

In regard to the technology review, researchers used the following approach:

a. An initial list of technologies was generated through a project team workshop to focus on precinct-scale technologies and systems and elicit a range of existing and emerging technologies relevant to high-density urban precincts,

b. This was then supplemented by a review of literature drawing on information from a range of technology, energy and water industry websites, peer-reviewed literature and industry and governmental reports. These were reviewed with respect to key trends and developments, barriers to sustainability and precinct related applications for energy and water technologies and systems,

c. This was refined further through a number of project team meetings and then a final round of literature review provided further detail on technologies considered promising or emerging. This was supplemented by additional feedback and review from key partners,

d. This document was developed concurrently with a global best practice review of precinct-scale energy and water applications which, together, will provide insights into opportunities for precinct developments such as in the case of the Broadway Precinct, Sydney,

The following research questions guided our approach in considering which technologies and applications are likely to contribute to low carbon precinct retrofit solutions out to the year 2040:

- What are key existing and emerging technologies and system-wide enablers that might contribute to low carbon energy and water outcomes for precincts, in particular retrofitting existing high density, urban precincts?,
- Which are the relative contributions to low carbon energy and water in precinct retrofits that these technologies could make?

3.2 Key Trends and Drivers for technologies at the Precinct Scale

A number of key trends evidenced in recent years have the potential to radically shift the speed of the transformation of the urban energy and water systems and the rate at which various technologies are taken and scaled up. Technological advances in building integrated solar PV, battery storage and smart control systems have the potential to impact the energy performance of high density precincts. Landscape trends such as growing awareness of planetary environmental constraints, evolution of the energy market and decreasing costs of large scale renewables will influence the timing and effectiveness of precinct technology implementations.

3.2.1 Environmental constraints

As scientific evidence drives further recognition of the extent of human-induced climate change and humans exceed the capacity of a number of planetary boundaries (Steffen et al. 2015) scientific, political and civil society are coming together to drive a new paradigm of eco-based business and industry to minimize the impact of humanity on local, regional and global ecosystems. This is resulting in a range of environmental restrictions and increasingly high scrutiny of development and businesses to improve performance in environmental credentials. In turn, a fundamental shift in approach to sourcing, use and management of resources is leading to significant investment in renewables and other low carbon products and services, rapidly improving the rate of uptake and overall business case for renewables and efficiency in resource use. Shifts from ‘do less harm’ (mitigation) to ‘do more good’ (impact) are underpinning systemic thinking in products and value-chains to create value within a low carbon and circular economy.

As the world’s climate warms, the demand for air conditioning will also rise. In addition, improved standards of living in developing nations and the movement of people to our cities, will mean that world energy usage attributed to air conditioning is set to expand rapidly in the future.

3.2.1 Evolution of the Energy Market

Large shifts are predicted in the Australian Energy market making it necessary to move on from the traditional energy utility business model. The Future Grid Forum (CSIRO, 2013) predicts mega-shifts for Australia’s electricity landscape out to 2050, driven through ‘low-cost electricity storage, sustained demand for centrally-supplied electricity and the need for significant greenhouse gas abatement.’ Concerns about issues such as energy security, environmental sustainability, and over-investment in the energy networks are triggering a shift in energy policy, technology and consumer focus. Across CSIRO’s Future Grid Forum its four scenarios project:

- declines in grid-connected electricity generation from about 2040, with on-site generation to provide between 18 and 45 per cent of generation by 2050,
- decrease inelectricity sector emissions to 55–89 per cent below 2000 levels by 2050 (CSIRO 2013, p.15).

According to the Australian Government, average electricity prices have risen by 70 per cent in real terms from June 2007 to December 2012. Spiralling network costs in most states are the main contributor to these increases, together with inefficiencies in the industry and flaws in the regulatory environment. A large share (in New South Wales, some 25 per cent) of retail electricity bills is required to meet a few (around 40) hours of very high (‘critical peak’) demand each year. Avoiding this requires a phased and coordinated suite of reforms:

including consumer consultation, the removal of retail price regulation, and the staged introduction of smart meters, accompanied by time-based pricing for critical peak periods (Australian Government Productivity Commission, 2013).

3.2.2 Reduced cost of Solar and other renewables

Solar PV is a mature, proven technology that is expected to become the biggest single source of energy globally by 2050 (IEA, 2014). Installed capacity of photovoltaics has grown at rate of 40% over the last decade. The IEA has doubled its forecast capacity for solar PV compared to previous forecasts. As the industry has grown, PV module prices declined with cost reductions of 22% for each doubling of cumulative capacity over the last few decades. Figure 2 illustrates the downward trend in levelised costs of electricity produced by various means out to 2030 summarised by the Australia Institute.

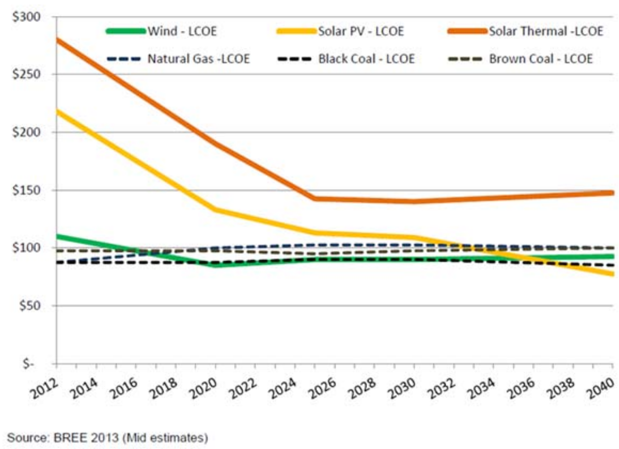


Figure 11 – Renewable energy cost trends

Much of the anticipated growth in solar estimated for Australia is attributed to large-scale solar farms which will primarily be located in regional Australia and used as a centralised plant, substituting fossil fuel generated electricity with renewable at the grid (ARENA, 2014). This will lower the average GHG emissions intensity in the NEM and potentially move peak electricity prices. The increasing renewable energy component of grid supply means that the carbon benefit of gas technologies will reduce over time. As the percentage of renewables in the grid increases, high efficiency electric chillers and heat pumps will have a lower greenhouse impact than gas turbines used for co- and tri-generation and gas boilers.

Not only are prices dropping but new innovations and developments in solar cell technologies are occurring and will rapidly shift the market as higher efficiencies in converting sunlight to electrical energy are achieved, for example in 2014 researchers at UNSW broke the 40% mark for efficiency of a solar panel, compared with 20% record in 1989 (UNSW, accessed May 5, 2015). These advances have the capacity to double solar energy contribution to the precinct. Case studies have shown that high density precincts can currently achieve < 5% of their energy demand from solar PV depending on their density and usage pattern. Bifacial modules, applied as building Integrated PV, are also set to gain niche markets in distributed generation.

3.2.3 Rise of Energy storage

Energy storage is a key component for creating sustainable energy systems. Current technologies, such as solar photovoltaics and wind turbines, can generate energy in a sustainable and environmentally friendly manner; yet their intermittent nature still discourages their adoption as primary energy supply. Energy storage technologies have the potential to offset the intermittency problem of renewable energy sources by storing the generated intermittent energy and then making it accessible upon demand, increasing the ability of renewable sources to be incorporated into the grid. As an increasing amount of renewable energy sources are incorporated into the grid, surplus energy could become more plentiful during daylight hours, instead of the night as is common currently. This in turn could have a disruptive effect to current energy tariff structures and necessitate the use of smart meters and time of use pricing.

Power storage at the precinct scale is not yet common but because applications exist both at the grid and the residential scale, it is likely that applications at the precinct scale will arise. In the precinct, commercial fleets of electric vehicles could be charged during the evening taking advantage of current off peak energy prices. A number of storage configurations are likely to emerge, either tapping into the electric vehicle batteries or separate battery banks attached to the system. Battery technology advances such as lithium ion and Vanadium Redox as well as the niche opportunities for ultra-capacitors, have the capacity to revolutionise our ability to use locally generated renewable sources of energy in the near-term.

3.2.4 The rise of microgrids

In initiatives such as the New York prize, highlight the new focus on microgrids as a potential solution to precinct scale low carbon transitions. According to the US department of energy, microgrids are:

'a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A MG can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode'. (REF)

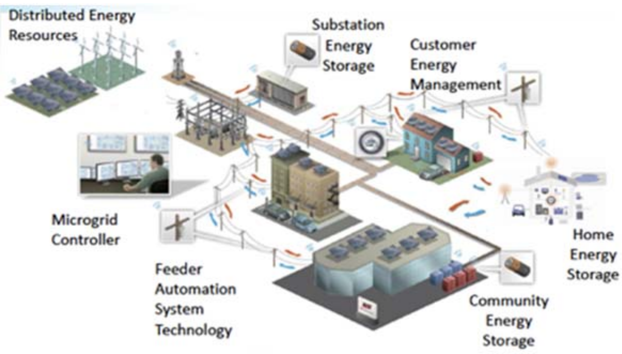


Figure 12 – Distributed networks

Microgrids have been widely deployed in university campuses, defense contexts and commercial/industrial parks, however, in the Australian setting they have typically been associated with off-grid and edge of grid applications.

In the context of a local district transition, microgrids are a way to draw together existing and emerging technologies and infrastructure with an overlay control system that is also able to interact and transact with the wider energy market. It is the potential for this interaction and related benefits such as demand management, ancillary services.

Utilities may actually end up buying power from a community-financed microgrid powered by wind or solar. Microgrids have the potential to be the basic core technology that will make smart grids possible and to significantly reduce fossil fuel dependence, reduce our need for large transmission lines, and improve the reliability of our electrical power because of these 'islanding' capabilities.

3.2.5 Smart, connected and engaged consumers

Another mega-trend in the energy market has been the emergence of new capabilities that are driven by the ICT revolution. In the energy world this should enable consumers to interact in real time. Around the world energy utilities are deploying smart meters with time of use pricing to help customers shift electricity usage away from peak periods and thereby reduce the amount of power generated by inefficient and costly peak-load facilities, and avoid costly network upgrades. At the precinct scale this could make the introduction of thermal, hydro and power storage even more economical, if the price difference between high and low demand periods was significant. For example, using off peak power to cool water for use at peak times may yield substantial cost savings.

Smart buildings embedded with IT that monitors and optimizes energy use could be one of the most important ways of reducing energy and water consumption in precincts. Low cost sensors used in commercial spaces could track occupancy rates, switching off air-conditioning and lighting when the spaces are not in use. Improved analytics and cloud computing make predictive building control a reality, improving occupant comfort, reducing energy and water use while optimising maintenance routines and fault monitoring by facilities managers. Performance data can be shared with a manufacturer, operator or consumer without human to human interaction.

Smart energy and water signifies a more integrated and distributed system, extending through the supply chain – from business, industry and residential consumers through to source/generation. The concept of the 'internet of things' (IoT) is relevant here. It refers to the rapidly expanding network of sensors and controls embedded into objects that allow direct connectivity between various nodes in the network.

Interconnectivity is a key feature that allows for a two-way flow of information and energy across a network, including information on pricing. Customers can trade surplus energy on new energy exchange platforms. They can find the best price for their power in the network, offered by a utility or a neighbour. Enhanced network performance and distributed energy allows greater efficiency but also resilience to emergency events like storms and floods, which are already increasing in severity, and are forecast to continue this trend well into the future. The whole smart electricity grid or water manager approach allows utilities to intelligently select what energy to tap into at any given time, including storage devices charged up from wind and solar, or idle back up generators in the basement of a commercial office block. This means that precinct assets could generate a return to the organisation while helping to reduce network upgrade costs for the whole community. Finally, faster internet speeds and flexible working conditions will allow employees in high density environments to work a few days per week from home, avoiding time lost on commuting. This could reduce the occupancy rate of some buildings, which will be compensated by hot desking and agile work environments for progressive organisations. Laggards may however experience an overall increase in overheads per employee, if space efficiency is lost.

The ability to connect to smart technologies is increasing control, involvement and choice for consumers in options for supply, management and use of energy and water. As new business models come into operation, electricity pricing shifts to become more cost-reflective, and a higher overall level of consumer engagement occurs.

In terms of management of energy and water, the need for low-powered/autonomous and cheap devices that enable customers to have immediate feedback on usage, network information and supply and storage will enable smart and sustainable cities and communities. A recent study found that 57 million customers worldwide were already using social media to engage with utilities in 2011 (Pike Research, 2014) with that number expected to rise to 624 million by the end of 2017. Although this research focuses on residential users, similar practices may emerge for building facilities managers.

On the supply side, increasing control by individuals or groups of their own energy needs is demonstrated by a range of community owned/operated models and partnership approaches to renewable energy. These small-scale systems operate independently of the existing local grid and are changing the role of utilities. Although the rate of this change is of significant concern to utilities as the drop in system electricity demand has created a potential 'death spiral'. The death spiral describes a future scenario where prosumers (individuals and groups proactively managing their own power resource and supply) leave the grid by investing in small-scale renewable systems, this in turn increases costs to remaining grid-connected customers as utilities seek to cover (in which over-investment in grid infrastructure to meet forecast demand that did not eventuated, leads to increased costs of supply to consumers). In turn this leads to more consumers investing in cost-competitive alternatives and leaving the grid and so on.

New business models including community energy generators and retailers may shift the current system structure further. ENOVA is a community owned energy retailer in northern NSW seeking to be established in 2016, as at the time of writing share offers were still open to the community and were very close to achieving the $3 million capital fundraising required by the regulator (http://www.enovaenergy.com.au accessed December 1, 2015). If this is successful, it would be the first community-owned retailer in Australia.

The next few years are crucial in determining how network businesses and utilities interact with the new, nimble organisations and entrepreneurs opening up energy and water markets and how regulators will view their role in this shift. Certainly, new skillsets and forms of dialogue between stakeholders will need to be developed to ensure the transition is a smooth one.

Table 6 and Table 7 provide a summary of low carbon energy and water technologies and their primary applications focusing on avoiding, reducing emissions or using new fuel sources. These includes systems and technologies that will improve efficiency of energy and water provision and use together with peak demand management technologies; zero carbon energy generation and low carbon, but not necessarily renewable, generation (i.e. lower than the current grid emissions factor) e.g. natural gas; energy storage systems and technologies e.g. batteries, electric vehicles to grid, chilled water storage etc.

3.3 Low carbon energy technologies

Table 6 Low Carbon Energy Technology and Applications

Technology Category		Technology	Technology Description	Technology Applications at Precinct Scale
1.Solar PV	1.1	Solar Photovoltaics (Solar PV) Panels	Solar PV Panels are a series of mono or polycrystalline solar cells using silicon to generate electricity directly from sunlight. Flat plate (dominant in the market) and solar collectors are the two main types.	At the precinct-scale, key considerations are required: roof space, roof structure, orientation and shading from other structures or trees. Different configurations - fixed-tilt, single-axis (east-west) or two-axis (east-west and north-south) tracking influence the productivity of the panels, with the latter providing up to 30% increase in annual production. At current efficiencies, PV panels are not a significant contribution to high density energy usage but may have greater application for warehouse configurations. Importing power from local generation sources in the neighbourhood is an evolving field in Australia. The Sydney Renewable Power Company connects available roof spaces to demand nearby. UTS has purchased solar power directly from a solar farm in Singleton via a power purchase agreement.
	1.2	Emerging solar	Emerging solar technologies like amorphous and thin-film solar are less rigid in structure than solar panels and although less efficient than flat-plate panels, efficiency improvements over time and the future room for improvement between R&D and commercial models (which typically have a 20-year lag time) show promise to replace crystalline silicon as the primary solar technology in future (EPRI, 2009). Developments in silicon cells could improve efficiencies in the near future reaching up to 24% by 2020.	Building integrated PV (BiPV) using thin-film solar technologies has the potential to replace existing building materials such as window glass. Key considerations include higher costs and lower efficiencies (currently) as the market for these is relatively immature but, as noted, significant growth is expected in the medium term. In addition, alternative production methods including printing have the capability of lowering technological costs in the long run (Savvakis & Tsoutsos, 2015). The highest profile example is the Willis Tower (formerly Sears Tower) in Chicago, where Pythagoras Solar installed a small prototype in 2011.

Technology Category		Technology	Technology Description	Technology Applications at Precinct Scale
2.Solar Thermal	2.1	Solar thermal flat plates	Solar thermal technologies are designed to harness sunlight for its thermal energy (heat). Flat plate collectors work through a series of copper pipes in a very well insulated glass box. As water or a heat transfer fluid is passed through the collector, the heat trapped from the sun is transferred into the fluid, which is then heated and circulated back through a heat exchanger, where the heat is stored for immediate or later use in domestic hot water or space heating systems.	This heat can be used for hot water and space heating in commercial buildings. Combined photovoltaic and solar thermal flat-plat collected (PV/T), combining electrical generation and water heating in a single unit, thereby producing higher overall efficiency with lower roof-space requirements (Michael & Goic, 2015). Similar to PV, solar thermal technologies do not make a significant contribution to high density energy usage but may have greater application for warehouse configurations.
	2.2	Solar Evacuated Tubes	Evacuated tube collectors consist of an array of evacuated glass tubes that have more flexibility in arrangement compared to flat plate collectors. The differing ratio of absorber area to footprint of system compared to flat plate means generally evacuated tube systems are more efficient per m^2. In addition, heat loss is lower in evacuated tube systems. However, lack of sun tracking, and sub-optimal performance in colder temperatures reduces their efficiency gains over flat plate collectors (Sabiha *et al*., 2015; Kalogirou, 2003; Morrison *et al.,* 1984). Compared with flat plate solar collectors, solar evacuated tubes provide larger surface area and can be heated to a much higher temperature which provide efficiencies.	Applications include centralised building plant such as pre-heating for gas boiler. The ability for flexible arrangement of tubes, and the smaller footprint required compared to flat plate collectors means evacuated tube configurations have greater application for building with low available roof space.
	2.3	Parabolic trough collectors	Parabolic-trough solar collectors (PTCs) use a curved mirror to reflect sunlight onto a single focal point. A single-axis tracking mechanism enhances concentration and conversion of direct solar radiation into thermal energy up to 400°C with a good efficiency. Combined with absorption chillers for cooling, PTCs can generate chilled water for air conditioning in commercial buildings. Many of the large solar farms and solar towers use PTC's with tracking to produce electricity via steam generation. These power stations can also use molten salt as a storage medium to enable extended operation.	At the precinct-scale, smaller parabolic troughs operating at temperatures 100-250°C can be installed on rooftop areas, to provide heating or cooling via absorption chillers. Although not widely used at this scale in Australia, they have been demonstrated to be commercially viable in Portugal at scales of <100kW (Quintal *et al*., 2015). They also offer the ability to generate heat up to 400°C gives PTCs application for industrial precincts, where demand exists for higher-grade heat.
3.Wind	3.1	Micro-wind (<1KW)	Micro-wind turbines are those operating at the scale smaller than 1kW. They are suitable for urban rooftops and open spaces. Most micro-wind turbines are horizontal axis turbines, however, vertical axis designs are becoming more common. Due to their small size, they are advantageous in providing a source of generation in	Urban environments are notoriously variable as a wind resource, and much of the existing wind is primarily for aesthetics and branding rather than significant contribution to GHG emissions reduction. There are additional challenges with incorporating micro-wind into urban areas, including compliance with planning issues, and the uncertainties of forecasting wind

Technology Category		Technology	Technology Description	Technology Applications at Precinct Scale
			space-constrained areas (i.e. rooftops), and can integrate well with photovoltaic systems.	resources (Sunderland *et al.*, 2013). As a stand-alone source of energy, micro-wind is not considered to be a significant contributor to low carbon outcomes for precincts within the time period.
4.District Heating and Cooling	4.1	Cogeneration and Trigeneration	Cogeneration (also known as Combined Heat and Power (CHP) or depending on the source, Waste Heat to Power (WHP)) is the simultaneous production of electricity and the use of waste heat from the generation process to supply heating and hot water needs (Kinesis, 2013). In a further step the heat produced can be converted into chilled water via a heat–driven chiller. This is known as trigeneration.	At the precinct-scale, cogeneration provides the most common internationally examples of precinct-scale low carbon energy. It can provide space heating, water heating, and heat for swimming pools. Cogeneration is often cost-competitive with other forms of heating, however the efficiency and capability dramatically decrease in warmer climates, particularly in the summer months, where there is minimum demand for heat (Jradi & Riffat, 2014; Lozano *et al.,* 2011). A balanced heat and electricity load is required for optimal efficiency for cogeneration systems. However, trigeneration can provide cooling in warmer months. Cooling technologies include electric (centrifugal) chillers using electricity from a cogeneration system, and absorption chillers. Due to their ability to use waste heat, absorption chillers have the most applicability in trigeneration systems, although come at a higher cost and larger footprint. There are many examples of cogeneration and trigeneration around the world, in applications such as apartment and office buildings, university campuses, and urban districts. City of Sydney has a Trigeneration Masterplan which outlines the vision for a network of trigen systems delivering directly to the HV electricity network across the city. Their waste heat will be fed into a district thermal pipe network to transport hot water across a series of Low Carbon Infrastructure Zones. It is estimated that Trigeneration, deployed on this scale, will raise the end–use efficiency of the fuel stock from approximately 35% (for coal–fired electricity) to at least 60%.
	4.2	Fuel Cells	Fuel cells are electrochemical processes that converts the chemical energy of a fuel, namely hydrogen from natural gas and renewable sources, to produce electricity and heat in small-medium scale applications. Low temperature fuel cells need a relatively pure form of hydrogen as fuel that requires conversion, often from natural gas while high temperature fuel cells internally convert the fuel to hydrogen at elevated temperatures.	Hydrogen fuel cells can be used for cogeneration at small-medium scales with negligible impact on local air quality. Low temperature fuel cells can harness waste heat and water to generate hot water and low-grade steam. High temperature fuel cells can generate higher temperature hot water and steam, and can reach system efficiencies of ~90% (Ellamla *et al*., 2015).
5. Waste to Energy	5.1	BioEnergy including	Bioenergy is the generation of electricity, gas, liquid fuels or heat from organic material such as food waste, green waste and/or	Waste-to-energy facilities could be located off site, or small-scale processes could be located within an urban precinct. There are numerous

Technology Category		Technology	Technology Description	Technology Applications at Precinct Scale
		Pyrolysis and Anaerobic Digestion	sewage. **Pyrolysis** is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen. It enables biomass and other waste sources to be converted to a combination of solid char, gas and liquid (often called bio-oil). **Anaerobic digestion** is a biochemical process that usually applies to biomass feedstocks with high moisture contents. Anaerobic digestion uses microorganisms to produce a biogas rich in methane, which can be combusted for heat or used as fuel in reciprocating engines for power generation.	anaerobic digestion technologies available for different feedstocks and applications. For urban precincts, scale will be a consideration and may require significant collaboration between councils, industry, businesses and residents to ensure an efficient supply and sourcing of appropriate feedstock. Anaerobic treatment of sewage waste is being trialled at Hamburg, Germany for a low density precinct.
6. Building Integrated energy generation	6.1	Building facade Algal 'bio-reactors'	Algae in the bio-reactor facades grow faster in bright sunlight to provide more internal shading. The 'bio-reactors' not only produce biomass that can subsequently be harvested, but they also capture solar thermal heat – and both energy sources can be used to power the building. Algae power has the additional advantage of taking CO_2 out of the atmosphere, though the amounts involved are not huge.	The trial example of this is BIQ in Hamburg which has been operating for just over a year. Analysis shows that each m2 of panel reduces emissions by eight tons a year. The building currently reduces overall energy needs by 50%, By providing shading as well as energy generation as it absorbs sunlight, multiple benefits are available to precincts. Applications in Sydney may be limited by summer temperatures which will kill the algae.
7. Storage	7.1	Batteries – Lithium Ion	Currently, the dominating energy storage device remains the battery, particularly the lithium-ion battery. Lithium-ion batteries power nearly every portable electronic device, as well as almost every electric car. Batteries store energy electrochemically, where chemical reactions release electrical carriers that can be extracted into a circuit.	Application at the utility scale and at the home scale (Tesla's power wall) may have impacts on the peak demand and supply across the precinct. Applications to a precinct environment may be feasible. Examples of this have been undertaken by Lendlease in Western Australia on Alkimos project where a precinct battery was installed to manage the PV peak demand and supply differentials. They are mostly used where the renewable supply exceeds baseline loads. A precinct enabled network solution may negate the need for battery in the short to medium term as it would relate to the precinct baseload rather than an individual buildings baseload.
	7.2	Batteries – Vanadium Redox	Flow batteries (i.e. Vanadium Redox) store energy in electrolyte solutions, counter to traditional battery storage systems in which electrodes are responsible (Zakeri & Syri, 2015). The main advantages of the vanadium redox battery are that it can offer almost unlimited capacity simply by using larger electrolytic storage tanks, with power ratings	With their superior storage capabilities, long life-spans and flexibility, flow batteries are a promising technology. However, their low energy density, limited operating temperature, and high capital costs mean that they are not yet commercially viable on a precinct scale. The largest reported flow battery is a 3MW system at Sumitomo

Technology Category		Technology	Technology Description	Technology Applications at Precinct Scale
			increasing with large cell compartment area. Flow batteries can also be completely discharged for long periods with no effect on performance unlike batteries such as lead-acid, and lithium-ion.	Densetsu Office in Osaka, Japan, specifically installed for peak shaving applications (Poullikkas, 2013).
	7.3	Electric Vehicles – vehicle to grid	Electric Vehicles have two main categories based on their independence from the grid: Battery EV's (BEVs) and Plug In Hybrid EV's (PHEVs). In relation to lowering the carbon intensity of the electricity system to urban precincts, the potential sits with PHEV's as a form of storage in low demand times while plugged into the grid.	PHEVs have sufficient range to meet the driving needs of the vast majority of urban dwellers. While the additional loads and potential to leverage the stored energy as a resource are unlikely to materially impact up to 2020, uptake between 2020 and 2025 in certain regions is conceivable. This makes EVs a potentially major consideration in urban infrastructure beyond the next ten years.
	7.4	Ultra/Super Capacitors	Capacitors store electrical energy for short durations. They can be charged substantially faster than batteries, and have lifespans of tens of thousands of cycles. Supercapacitors store energy by means of an electrolyte solution between two solid conductors, and have very high capacitance. The energy storage capabilities of supercapacitors are substantially greater than that of conventional capacitors (Chen *et al.,* 2009).	At a precinct scale, super capacitors can be used within microgrids to maximise operation capacity through power quality services, manage peak loads and buffer power surges.
	7.5	Low Temperature Thermal Energy Storage (TES) e.g. Ice or Chilled Water Storage	Thermal energy storage (TES) uses material that can be kept at high/low temperatures in insulated containments (Chen *et al*., 2009) Heat or cold air can be recovered and used for building heating/cooling requirements, thereby improving existing building cooling performance. TES systems can be categorised into either low-temperature TES (sub-zero to ~12*C), or high temperature TES (25-50*C for building heating. Typically, in district energy systems cold water or ice is generated in off-peak hours, and used to meet cooling demand during peak hours, allowing for smaller chillers and lower air-	TES can be applied to cooling loads ranging in size from small schools to large office buildings, hospitals, arenas and district cooling plants for campuses or other urban developments. TES technology is well suited for integration with renewable energy sources, where a storage system can overcome problems with intermittency.

Technology Category		Technology	Technology Description	Technology Applications at Precinct Scale
			conditioning demand (Heier *et al*.. 2015).	
	7.6	Pumped Hydroelectric Storage	Pumped water storage consists of two reservoirs, each capable of storing large amounts of water at a significant elevation difference. Water is pumped from the lower reservoir to the higher reservoir during off-peak electricity periods, or when renewable energy can be stored rather than used directly. During times of peak demand, this extra stored water can be released from the higher-elevation reservoir and run through the pump (operating in reverse as a turbine) to generate electricity, which can be used to offset local usage.	Currently there are few examples in urban precincts. Capital costs and physical constraints (such as roof area and building support structures) would be limiting factors to its application in high density environments.
8. Energy Efficiency	8.1	Multiple building efficiency technologies	Energy efficiency can contribute to avoiding and reducing emissions through reduction in demand for energy. Various technologies in building efficiency are available particularly focusing on design principles in retrofits and upgrades that reduce the need for heating, cooling or lighting loads and/or addressing load through more efficient upgrades to HVAC and lighting systems. Efficient appliances and equipment, automated controls linked to management practices such as wider temperature set points, variable speed drives for pumps, motors and fans and automated outside air controls are all relevant here. Energy efficiency is particularly linked to smart metering and ICT systems such as building management systems.	Building-level energy and water efficiency actions are relevant at the precinct-scale, however, currently precincts with one property developer/building owner and manager operating can enable efficiencies at this scale more easily than multiple ownership. New precinct approaches that employ collaborative business models between building owners, joint procurement policies and system controls that manage multiple buildings will enable more efficient precinct-scale management. *This is covered further in the global best practice review section*.
9. Harbour Heat Rejection			Harbour heat rejection (also seawater heat exchange), is a cooling process which typically circulates cold water for air-conditioning or other cooling applications, sending warmed water back to the reservoir to repeat the cycle. This limits the need for expensive plant equipment and cooling towers.	This type of seawater heat exchanger is in operation at several sites within Sydney Harbour, including the Sydney Opera House, Star City Casino, and the North Sydney Olympic Swimming Pool. Key considerations include climatic factors particularly ambient air temperature which can constrain free cooling applications. Local site

Technology Category	Technology	Technology Description	Technology Applications at Precinct Scale
			factors are also key considerations, particularly if there is shipping. This requires piping for the heat exchanger to be installed to reduce shipping hazards. The complexity of these systems would also make available capital a key constraint. For applications in buildings, it is commonly used for air conditioning in European Buildings. Free cooling is efficient compared with other cooling methods and can reduce or replace parts of mechanical refrigeration that requires high energy consumption to operate.
10. Microgrid		Although microgrids are a combination of many of the technologies outlined above, the addition of a centralised microgrid management system (MGMS) differentiates this technology and warrants individual consideration . A microgrid control system typically includes algorithms that enable optimal generation mix, predictive algorithms that take into consideration climatic conditions, frequency and voltage control, islanding functionality, demand management capabilities	At a precinct scale, microgrid control systems create opportunities to manage demand of significant loads as a block and optimise the generation and storage utilisation locally. This functionality could also be used to bid into the market and to buy from the market based on conditions. In a highly developed microgrid environment it would be possible to prioritise loads across an entire precinct based on the ability to defer loads or constrain supply based on an understanding of load types at a granular level.

Water services provision and efficiency

The following technologies and systems relate primarily to the provision of potable water in urban environments. Although it is noted that there is some overlap between some of the energy system technologies in Table 1 above and those listed below, primarily these relate to water service provision and consumption.

Table 7 Low Carbon Water Technology and Applications

Technology type	Technology Description	Technology Applications at Precinct Scale
1.Rainwater Collection and Reuse	Storage tanks can capture roof water runoff, and can be combined with some form of treatment e.g. ultraviolet (UV) treatment or microfiltration to improve water quality, however, most rainwater supply is used in non-potable applications such as gardening and toilet flushing (An *et al.*, 2015). A key consideration for rainwater systems is the space requirements associated with storage volume and the energy cost for pumping. Trade-offs between rooftop and ground level storage exists because while ground level storage is more cost-effective and has greater	Rainwater has some advantages for use in cooling towers also, because of low TDS and in some instances has been used for potable water supply (John Gorton Building, ACT) or for hot water (Central Park)

Technology type	Technology Description	Technology Applications at Precinct Scale
	capacity, it will increase cost of pumping up in multi-storey buildings. Tank volumes depend on rainfall patterns and in some instances can reduce the runoff and usefully reduce the cost of stormwater.	
2.Stormwater collection, reuse and treatment	Stormwater can be collected from runoff from impervious surfaces surrounding a building from areas other than the roof and treatment and reuse, mostly for non-potable supplies. Sometimes this involves the use of a stormwater retention basin.	Key design issues are associated with storage volume (although sometimes a retention basin can be used) and ability to capture storm events, dependent on rainfall patterns. Water quality is lower than in the case of roof-water collection, and can contain toxins and heavy metals that need to be removed before it can be reused (Liu *et al.*, 2015). Energy is required for effective reuse of stormwater. There is also not clear economic model for re-use of stromwater.
3.Local Wastewater Treatment	Wastewater can be captured and reused with varying degrees of treatment. These systems can collect effluent from a site, or can intercept sewerage water prior to discharge to a sewer. Direct wastewater systems use reclaimed effluents for potable and non-potable applications. Non-potable uses in an urban context include urban park irrigation, industrial uses (cooling, processing), fire-fighting, dust control, and toilet flushing (Garcia & Pargament, 2015) Wastewater reuse is beneficial, as compared to storm/rainwater collection, it is relatively constant throughout the year (Friedler, 2001)	Key considerations are the treatment of biosolids contained in the wastewater, which is often discharged to the sewer. Cost is also a consideration, as treatment processes become more complex. This is particularly relevant depending on the end-use of the treated water, as potable water would need to meet more stringent standards, thus require greater treatment. Various treatment options exist including thermal treatment, mechanical treatment including microfiltration, chemical treatment using disinfectants, and biological treatment. There are varying levels of energy requirements for treatment, however, biological treatment options typically have low energy requirements making it suitable for integration with distributed renewables (Mennaa *et al*., 2015). Wastewater treatment at the Central Park, Broadway precinct consists of several integrated treatment processes, including mechanical (i.e. screening and microfiltration), biological (i.e. anaerobic, aerobic and ultraviolet), and chemical (i.e. additives including chlorine) treatment.
HVAC and Cooling Towers	HVAC and Cooling Towers can use significant water quantities. Seeking efficiency upgrades or management of these assets can yield significant water savings.	Upgrading HVAC's and Cooling Towers to air cooled or considering a regular maintenance reviews and leak detection can significantly improve water efficiency of these assets. There may also be possible to consider alternative water supplies for these systems.

3.4 Precinct Technology Assessment

In this section, we provide potential approach to determine the of the current potential of low carbon energy and water technologies to inform further assessment of their applicability within an urban precinct retrofit. Within a precinct transition a clear and justifiable technical assessment framework would be essential to enable effective decision making.

Provides a methodology for assessing a range of technologies (in order of those provided in Tables 1 and 2 above) against the following criteria:

Primary benefits of the technology have been categorised for ease of reference as:

- Zero Carbon Energy (ZC),
- Energy Efficiency or reduced demand (E),
- Water Efficiency or reduced demand(W),
- Peak Demand (PD),
- Other (O) - includes broader sustainability benefits such as waste reduction, social inclusion, biodiversity, reducing heat island effect.

Although all technologies to some degree will contribute to multiple categories, this considers the primary benefits.

Precinct Considerations – in this context ,precinct considerations relate to how this technology might be applied in high-density urban retrofits. Although context is extremely important, some generic indications and common configurations are listed where available. Relevant ownership, regulatory factors or, commercial or financial considerations that would affect the indications of cost and potential impact are noted.

Technology Maturity Timeframe - it represents the indicative timeframe for this technology to be readily available in the market with few technical or regulatory barriers to drive adoption (however, financially the technology may still be subsidised to some degree). This occurs relatively independently of the precinct considerations and other factors. In this categorisation, the timeframes are as follows:

- S= short-term, 0-5 years
- M= medium-term, 5-20 years
- L= long-term, 20+ years

For example, solar PV is considered Short-term, even though some subsidisation takes place through Feed-in-tariffs and large-scale generation certificates (LGCs) and small-scale technology certificates (STCs)

Unit Cost – it represents the full costs associated with this technology to provide the service (energy or water) to customers. Low, medium and high are factored in relation to the current cost of providing the service.

- L = Low, negative to current cost
- M = Medium, current to +50% of current costs, and
- H = High, 200%+ of current costs

Potential Impact –it indicates the percentage contribution this technology could make (based on current maturity trajectory) to precinct energy (electricity) and/or water demand. In most cases this is total demand, but where

It is indicated as:

- L= Low, up to 2%
- M= Medium, between 2-10%
- H= High, 10-50% contribution to demand.

In some cases, where in excess of half of the demand could potentially be met by this technology within the timeframe, this is indicated as Extremely High.

Table 8 Precinct Technology Assessment

	Barriers	Opportunity
Economics of district infrastructure	High capital costs for district infrastructure plus high network costs. Low remuneration for power sold back to the grid from local sources.	Economies of scale enable efficiency gains, decreasing operating and maintenance costs as well as increasing available floor space.
Energy prices	Fluctuating energy and gas prices can make distributed infrastructure business cases less robust – especially for technologies that rely on gas.	Introduction of time of use pricing and smart metering may make local renewable energy and (thermal and battery) storage technologies more viable.
ICT	Limited understanding of advanced control systems in the facilities management sector.	Smart building revolution will reduce building energy demand and optimise the use of decentralised energy generation and storage infrastructure.
Roof Space	Competing uses for roof space such as solar PV, roof gardens/ recreational space and cooling equipment.	Offsite purchase of chilled water can free up roof spaces for other uses.
Refrigerant changes	Many refrigerants with high global warming potential will be phased out in future years.	Chillers will need significant upgrade or replacement which could present a window of opportunity for precinct businesses to consider more efficient chillers or offsite purchase of cooling water.
Future Proofing	Changing power usage patterns caused by working from home, increased hours of operation, uptake of precinct electric vehicle fleet, hot desking, and other agile work practices.	New control systems that respond to occupancy numbers and can predict energy usage patterns will become increasingly viable.
Central Network Costs	Increasing costs to replace aging network infrastructure in high density environments.	Opportunity to increase decentralised infrastructure component with corresponding carbon reductions and productivity gains.
Central grid decarbonization	A high proportion of renewable generation integrated into the grid will eventually make gas technologies less sustainable than efficient electrical equipment like heat pumps and electric chillers within the next 30 years.	Gas replacement by syngas and biofuels currently being investigated.
Regulatory	Continuing privatisation of the energy sector and the flow on effects to the NEM. Utility rules that discourage local generation.	Consumers empowered by social media and technology choose more sustainable energy suppliers promoting government action on climate change.

4.0 Precinct Governance

"There are many ways that energy infrastructures, that support the social and economic life of the city and that produce particular ecological consequences, can be shaped and that potentially different coalitions of social interest can claim to speak on behalf of the city."

Mike Hodson & Simon Marvin (2010)

The precinct scale often has no pre-existing governance structure, i.e. there are no established institutions, roles, relationships and procedures to draw on to make collective decisions around capital works or infrastructure maintenance or raise funds. This is both a draw back and a benefit. Without pre-existing structures in which organisations and individuals can participate, collective decision-making will be difficult. However, with no preconceptions, innovators can come together to write their own rules, set behavioural standards and in-formal codes of practice to achieve different outcomes to business as usual.

The concept of governance at a precinct level is usually associated with the implementation of infrastructure that requires long term ownership, operations and commercial management. Governance at a district scale has some significant challenges as it sits between the governance of a single entity, who has full control over its own assets (such as a university), and an entity such as Ausgrid who has a franchise right over an entire sub-region of the state. The social license to operate is clear in both cases, in the former it is based on fundamental property rights and in the latter through a regulated asset base structure that delivers socialised cost of services.

Governance in the creation of social or economic infrastructure goes through a number of phases. The first phase is the discovery process, where value is analysed and estimated. The next phase is where the estimation is tested through more detailed investigation including detailed techno-economic design. The next phase is the governance of the construction process and finally the implementation of the long term regulatory and/or contractual mechanisms that will ensure that the new social infrastructure is managed in a way that delivers benefits in a manner that is compliant with legal constraints and social norms.

An actor that seeks to implement precinct based infrastructure must ask themselves core questions at each stage of the transition:

- What stakeholder interests must be managed in order that this value can be captured?,
- What are the risks in trying to capture this value and who is best placed to take specific risks involved in capturing this value, and
- What mechanisms can be put in place to ensure that there is a clear social license to operate in place? Who ensures that accountability, equity and transparency are maintained?

Long term governance at a local scale will only emerge if enough measurable value is created to contend with the higher degree of stakeholder complexity that comes with operating at this level of engagement. Having said that, there are certainly environments that are more conducive to a transition occurring. As such, it is both the identification and articulation of value, and the creation of the conditions that are conducive to a transition that will maximise the likelihood of a transition occurring.

4.1 Initiating the transition

"when we talk about an urban low-carbon transition we are referring to a re-scaling of the energy regime, in ways which transform the city as well as the energy regime and that also require the development of—and the "intermediary" organization of—the capacity to act in undertaking such a transition."

Climate Change and Sustainable Cities

The need for governance emerges out of an initiative to capture value by a particular actor or set of actors. There are principal actors and agents of these actors who drive new infrastructure approaches. Principal actors who typically own infrastructure bring together and integrate technical, commercial and regulatory issues and will have long term social and a contractual license to operate in the precinct. Agents will typically be energy services companies, suppliers, consultants, or operators who bring ideas about how to create and capture value. Value can be identified by various stakeholders including government stakeholders, commercial investors, or proactive major local institutions who are willing to build own and operate infrastructure. Newer community ownership models are emerging, however they are yet to have significant impact on these types of projects in high density environments.

At the initiation phase key stakeholders are outlined in the following table.

Table 9 Stakeholder Typologies

Stakeholder typologies	Examples
End Users	Building owners, managers and occupants (organisations and individuals).
Private Services Industry	Feasibility and design consultants, construction companies and operators; water and energy service and product providers; private utilities and investors.
Not for profit	Green groups, community groups, industry advocacy and professional associations.
Government	National, State and Local Government (especially regulators and planners), Public Utilities.

The following table articulates the types of value that participants are attempting to identify and capture.

Stakeholder Types	Occupant comfort, productivity and morale	Secure competitive return on investment	Minimise utility bills	Minimise service interruptions	Social responsibility and increased market share	Maximise usable floor space	Sell alternative services	Urban resilience to power outages, storms and droughts	Liveability/Urban Greening/urban heat island effect	Reduce GHG impact	Stimulate economic activity	Decrease network capital investment by reducing peak demand	Alleviate fuel poverty	Preparing Industry for Change
Building owners/ property trusts		•	•		•	•								
Building Operators	•		•		•					•				
Occupants (organisations and individuals)	•	•	•	•	•					•				
Infrastructure designers, construction contractors					•		•							
Private utilities					•		•							
ESCO's and energy management companies					•		•							
Financiers		•												
Not for Profit Sector								•		•	•		•	
Industry Associations										•				•
Local Government								•		•	•		•	
Central Utilities					•		•			•		•	•	
Environmental Regulators										•			•	
Resource Price Regulators			•								•		•	•

End users, including building owners, occupants and operators are perhaps the most critical stakeholders. While other players can discovery and measure value, ultimately it is these players who will need to be provided with enough of the value to agree for a project to proceed.

4.2 Conditions that are conducive to a transition

There are several observable pre-conditions that will drive a successful transition – government position, local community co-ordination, a progressive utility and private innovator. In several of the reviewed cases studies, the value of stakeholder collaboration became clear. The benefits of the presence of various stakeholders to a water or energy reduction project is summarised in Table 10.

Table 10 Stakeholder collaboration

Stakeholder typologies	Benefits to project
End Users	• Organisational competitiveness drives social / environmental outcomes to enhance reputation and improve marketability (potentially making lower IRR investments more appealing).
Private Services Industry	• Access to private sector finance. • Design, construction, operation, project management expertise.
Not for profit	• Enhanced social/environmental outcomes. • Integrity or motives and outcomes. • Use of existing social networks.
Government	• Access to public sector finance. • Holistic planning. • Projects meet social/environmental outcomes stated in government planning documents. • Assistance with regulatory processes. • Utility participation allows the benefit of peak reduction to be captured.

4.2.1 The role of government

Government stakeholders include national, state and local government departments and government owned entities such as utilities. Government stakeholders have a disparate and often conflicting variety of drivers. For example, in Australia resource price regulators (such as IPART) are driven to provide the lowest cost resources to the community to stimulate growth and improve living standards, state owned utilities often provide dividends to the government and so are rewarded for increasing sales of water and energy (because of the throughput driver) both of which directly conflict with the environmental regulator's goal to reduce carbon emissions and save water.

International drivers were observed to vary from context to context. For example, in America, energy and water supply security is a significant issue as is resilience to major storm and other events that can cause extended power outages. The New York state government is seeking strategies to make community emergency centres and refuge points particularly self-sufficient in terms of power outages. In Australia, the urban resilience driver would be weaker as power outages in high density environments have been less common.

There is little doubt that long term, consistent policy with bipartisan support at the national and state level is highly influential in terms of achieving low carbon outcomes such as in the case of the Copenhagen District Heating Schemes (See Box 3). However, local governments are emerging as strong supporters of low carbon projects at the precinct scale. Policy has been shown to be more successful when the policy mechanism incorporates elements of education and project implementation assistance i.e. direct engagement with the target sector and integration of technologies into daily routines (Dowling, McGuirk & Bulkeley 2014).

Box 3 - Copenhagen District Heating Schemes

The City of Copenhagen is an example of consistent "top down" (i.e. government driven) policy support for district infrastructure, which is often held up as an international success story. 98% of the city is heated by a combined heat and power scheme, which has decreased emissions by 40% compared to individual gas boilers. This has been brought about by consistent bipartisan policy, across all levels of government, over three decades which is summarised in the table below. With national guidance, institutional arrangements, market regulation and utility rules were brought into alignment with fuel security and later carbon reduction and distributed energy goals (Future of London 2012). Today, district heating in Denmark has strong legislative backing under a series of Heat Laws. Municipalities are required to undertake heat mapping, to determine the appropriate energy distribution infrastructure. All retailers of heat are legally obliged to be not-for-profit and are therefore either cooperative, mutual or municipal companies. The municipal companies own and operate the transmission and/or distribution systems, while the cooperatives, mutual or municipal companies undertake the retailing of heat directly to customers (United Nations Environment Program, Copenhagen Centre on Energy Efficiency, ICLEI, & UN Habitat, 2015).

Table 11 History of district heating in Copenhagen (Future of London 2012)

Date	Policy /Event
1970	Rising concern over fuel security.
1984	Copenhagen Heat Plan released, local connection mandated.
1986	Co-generated Heat and Electricity agreement required utilities to provide capacity for 450MW of electricity via decentralised CHP.
1988	Ban on electrical heating in new buildings.
1990	Local authorities mandated to oversee the conversion of District Heating providers that produced heat only to CHP providers.
1992	Subsidies for renewable electricity production were also extended to CHP.
1994	Electrical heating in existing buildings banned.

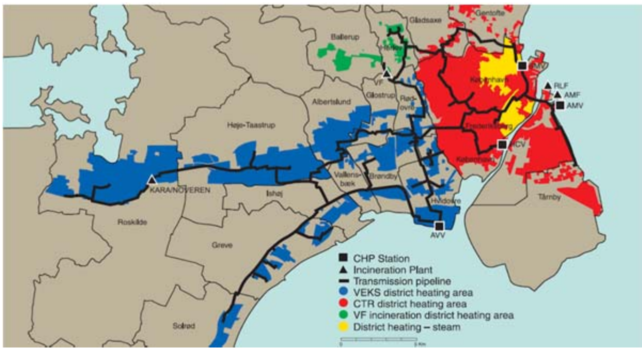


Figure 13 District heating in the Greater Copenhagan area

Source: Copenhagen Energy

Leading state and national governments have been embracing a more collaborative style of problem solving and experimenting which could influence the uptake of precinct scale innovation. Notably.\ the New York State Government has initiated the New York Energy prize to facilitate collaboration between communities, technical specialists, local and state government regulators and energy utilities to develop micro grid projects (See Box 4 below).

Box 4 - New York Energy Prize

The New York State government has used a competition engaging multiple stakeholders to find collaborative solutions to resilience to major storms and network capacity restrictions. The New York State Energy Research and Development Authority (NYSERDA), in partnership with the Governor's Office of Storm Recovery (GOSR) announced the availability of up to $40,000,000 under the three-stage New York Community Grid Competition, to support the development of community micro grids. The NY Prize targets communities vulnerable to storms and power outages. The proposed micro-grid must include critical infrastructure such as hospitals and police stations and/or a community refuge such as schools, libraries or shopping centres which can be used as a safe shelter during severe weather events.

High load growth areas nearing peak capacity were preferred, hence obtaining buy in from the utilities. Utilities provided a capacity constraints map (Figure 15) for the electrical network to identify areas where micro-grids would be most beneficial to the network. Community support was vital for successful bids.

The prize provides three stages of funding:

Stage 1: up to $100,000, Feasibility Assessment,

Stage 2: up to $1,000,000; Audit-Grade Detailed Engineering Design and Financial /Business Plan,

Stage 3: up to $25,000,000; Micro-grid Build-out and operation, monitoring and evaluation.

(New York State Energy Research and Development Authority 2015)

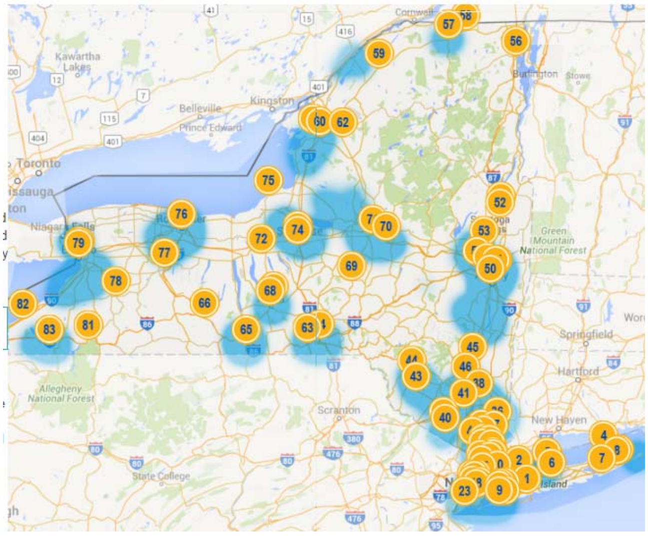


Figure 14 New York Energy Capacity Constraints Map

Facilitation and education around policy implementation fall to local government. For example, in order to facilitate ambitious targets for decentralised energy, the Greater London Authority has adopted various facilitation techniques:

- Produced the London Heat Map to identify potential decentralised energy schemes. Other cities, such as Amsterdam and Copenhagen, have also produced similar maps,
- Set up the Decentralised Energy Master Planning (DEMaP) programme to help local authorities identify projects (based on the London Heat Map), prioritise projects and create energy plans,
- Set up the Decentralised Energy Project Delivery Unit – to help local boroughs with technical, financial and commercial assistance for project delivery,
- Produced the London Heat Network Manual (GLA and Arup, 2013) to provide standardized guidance for developers, network designers and energy producers on the delivery and operation of district energy projects (Gagliardi La Gala, 2014).

Local governments have initiated policy which has traditionally been the realm of national governments. Notably, the Tokyo Emissions Trading Scheme, the world's first cap and trade program at the city-level targeting energy-related CO2. The Emissions Trading System (ETS) covers around 1,340 large facilities including commercial, public and industrial buildings. The City aims to reduce emissions by 25% from 2000 levels by 2020. CO2 reductions are aimed at 6-8% of 2000 levels by 2014 with a further 17% reduction by the end of 2020 (Padeco for the World Bank 2010). By 2014, more than 90 %of facilities covered by the system had achieved the 6 - 8 % targets with 70% of the facilities having already met the phase two goal. Organisational energy efficiency projects were largely used to meet the targets with only 22 carbon trading events recorded (Kaneko 2014). This scheme provided the right incentives to implement commercially viable energy efficiency upgrades.

Government-initiated and owned projects are the most prevalent district energy schemes in the world (United Nations Environment Program et al. 2015). However,non-centrally developed "bottom-up" (customer-led) infrastructure development was evident in cases studied. These initiatives often follow a nodal development pathway, as suggested by the International District Energy Association (IDEA, 2013), where a small plant serving a large anchor load (such as a hospital, university or several large buildings) gradually become connected to more and more neighbouring customers. Schemes are usually built in phases requiring waves of capital investment. Literature suggests that, eventually, two or more nodes will benefit from interconnection to a transmission backbone or trunk main that can utilize larger heat sources from further away to the original customer base, servicing a higher percentage of the city's residents and commercial buildings. It is very difficult for the private sector to deliver the business model for the trunk main. Many cities have interconnection plans which rely on municipal ownership (United Nations Environment Program et al. 2015).

From the cases studied, it was evident that holistic planning from local government bodies also encourages efficient resource deployment at the precinct scale to achieve city-wide goals. The City of Amsterdam energy atlas aims to develop energy savings scenarios which consider infrastructure upgrade, retrofitting existing building stock and urban planning optimisation (see Box

5 below). The City of Sydney used a green infrastructure master plan to scope potential projects to move towards its goal of a 70% emissions reduction by 2030 (see Box 6 below).

Box 5 Amsterdam Energy Atlas

The City of Amsterdam has developed an Energy Atlas as a way of identifying potential energy savings projects and district energy schemes, progressing the local energy strategy for the city. According to the City of Amsterdam, initiating projects is about finding the right combinations of stakeholders to create new, scalable business models, with potential customers being part of the development. The city collects the data in collaboration with local stakeholders, including businesses and property owners. The data is made freely available on an interactive atlas on the city's website. The data is analysed together with the different stakeholders to identify opportunity areas or zones for district heating, cooling and power. The involvement of stakeholders in the analysis phase helps to build trust in the analysis outcomes.

The aim of the Atlas is to develop energy savings scenarios which consider infrastructure upgrades, retrofitting the existing building stock, and to optimize urban planning. Data collected to date includes:

- thermal and electricity production (including waste heat) and consumption,
- existing and proposed sustainable energy projects,
- opportunities to connect to existing sources,
- energy network data,
- building stock (size, construction date, density, ownership potential for energy saving and local/renewable energy generation),
- willingness to invest or launch initiatives,
- modes of transportation,
- potential sites for thermal storage in the city centre.

Box 6 City of Sydney Green Infrastructure Master Plans

The City of Sydney has outlined a vision to:

- - reduce greenhouse gas emissions in the LGA by 70% compared to 2006 levels (City of Sydney, 2010),
- - meet 100% of its energy needs with locally produced energy.

In order to meet these goals a series of green infrastructure master plans were outlined, the first of their kind in Australia. The strategy can be summarised as:

- An energy efficiency reduction target of 14%, primarily met by street lighting retrofits, building upgrades and the expected improvements in appliances energy efficiency,

- Renewable energy harvested from within and outside the LGA will contribute to a further 18% emissions reduction. Building scale renewable energy schemes based on micro turbines, solar thermal and solar PV technologies as well as precinct or district schemes based on wind turbines, concentrated solar thermal and geothermal technologies will be installed within the LGA. Utility-scale renewable energy schemes outside the LGA likely to be based on onshore wind technologies within 250km of the CBD,

- A decentralised trigeneration network to contribute a further 32% emissions reduction. The district heating scheme would utilise distributed gas reciprocating engines to produce power and low temperature hot water to buildings within a defined low carbon district. Building owners would then use this heat to power private adsorption chillers. If the natural gas used to fuel this network was replaced by "renewable gas" or "syngas" a further greenhouse gas reduction of 19% would be possible.

Many local governments worldwide have programs to encourage demand-side energy efficiency retrofits in the commercial building sector; for example:

- London Better Building Partnership

- Sydney Better Building Partnership,
- Melbourne's 1200 Building Program,
- Retrofit Chicago's Green Building initiative,
- LA Commercial Building Performance Partnership

However, these programs operate over the local government scale rather than the precinct scale. Organisations like EcoDistricts have applied general information and strategies produced by these types of programs to specific precinct contexts with great impact (See Lloyd Ecodistricts Case Study).

The table below is a brief summary of local government policies which have brought about or could potentially bring about change at the precinct level, including best practice examples.

Table 12 Policy Instrument Summary

Policy/Program	Examples
Local Carbon Strategy	Tokyo Emissions Trading Scheme, the world's first cap and trade program at the city level targeting energy-related CO2. (Padeco for the World Bank 2010), (Kaneko 2014)
Building Code Enforcement	Californian building code "Calgreen"– mandates the inspection of energy systems by local officials to ensure that heaters, air conditioners and other mechanical equipment in non-residential buildings are working efficiently(Novotny 2010).
Green Enterprise Zone	False Creek Flats Green Enterprise Zone, Vancouver —zoning to support green innovation, green buildings and infrastructure, supports sustainability-related industries, attracts new green capital(City of Vancouver 2016).
Master Plans	Sydney Green Infrastructure Plans, London Authority's Decentralised Energy Master Planning (DEMaP)
Energy Mapping	The City of Amsterdam's Energy Atlas facilitates the development of energy savings scenarios which consider infrastructure upgrades, retrofitting existing building stock and urban planning optimisation. The Atlas is also a tool to engage private companies in energy data collection and analysis.
Connection Requirements	In Dubai, all public sector buildings and new developments are required to connect to the district cooling system.
Integrated land use and infrastructure planning	In South West Germany, Burgen's Masterplan identifies densification along a proposed light rail corridor coupled with expansion of a district energy scheme.
Targets	Greater London Authority's decentralised energy target, California's energy storage target.
Low Cost Finance	City of Sydney's Environmental Upgrade Agreement (EUA) used to finance energy upgrades with loan repayments paid by occupants as part of their council rate payments.
Transitions Management methodologies for Council planning	Rotterdam used the transition management approach to find innovative solutions for its climate change adaptation strategy. Change agents develop innovative strategies (including floating buildings and "water Squares") to solve problems supported by local government actors.
Development Requirements	In Tokyo new developments > 50,000 m^2 are required to set targets for energy-saving performance. For buildings > 10,000 m^2 or developments > 20,000 m^2, developers are also required to submit a district energy feasibility study. A similar approach is taken in Seattle and Vancouver.
Sustainability Organisations	City of Portland originally funded the Portland Sustainability Institute, the precursor of EcoDistricts, a self-funded collaborative urban renewal activator, which targets project implementation on the precinct scale.
Pre-feasibility Study Funding	EcoDistricts in Portland Oregon identified pre-feasibility funding as a major barrier to district energy projects. Since these studies are undertaken early in the innovation process to help convince stakeholders that a viable project exists the potential for repayment is limited.
Commercial Building Efficiency	Many local governments worldwide have programs to encourage demand side energy efficiency retrofits in the commercial building sector, for example: Sydney Better Building Partnership, Melbourne's 1200 Building Program, Retrofit Chicago's Green Building initiative and LA Commercial Building Performance Partnership.

4.2.2 The role of the precinct actors

For an established neighbourhood, a history of cooperation or existing positive business relationships, seem to be a prerequisite of establishing a productive governance structure. For example, the success of the Lloyd EcoDistrict and, in particular, the formation of a collaborative governance structure, was partially attributed to the history of collaborative governance in the precinct (Ecodistricts 2015). Evidence of collaborative governance structures have existed in Portland between government and civic partners since 1994 with the evolution of the Transportation Management Association (TMA). The TMA is a partnership between the City of Portland and public transportation agency, TriMet, founded to effect significant change in commuter mode choices and influence transport planning (Portland Sustainability Institute 2011d). The TMA supported investment in the Portland Street Car, which utilised an innovative local funding mechanism: a local improvement district tax on property owners near the line. Portland also has a history of commercial property collaboration with the establishment of a Business Improvement District (BID) in 2001, which aimed to facilitate transportation, public safety and economic development programs for the district (Berry 2010). Originally, the Lloyd EcoDistrict was a sub-committee of a Business Improvement District (Portland Sustainability Institute 2011e) and a business tax collected by the BID funded the first full time EcoDistricts coordinator (Overdevest 2011). Because Lloyd EcoDistricts members had positive experiences collaborating with other businesses to meet common goals in the past, the EcoDistricts method had a much higher chance of success in Portland.

Other factors that impact on uptake of sustainability projects at the precinct scale are organisational values. For example, in both Portland and Seattle, businesses valued smart leadership. Both EcoDistricts and 2030 Districts give their members logos so that they can identify their businesses with smart leadership, potentially gaining market advantage over competitors.

Current organisational practices will also impact on uptake of sustainability innovation. For example, management practices outlined in the table below have been positively correlated with organisational energy efficiency (Warren Centre for Advanced Engineering 2009; Crittenden 2014).

Table 13 Factors impacting uptake of transitions

Factor	Explanation
Staff Engagement	Staff and other stakeholders are engaged in constructive collaboration to improve energy management. Staff needed to be involved and engaged in problem solving not just consulted.
Management	• Integrating the efficient management practices within existing business systems, including establishing role descriptions and accountabilities for relevant staff across their organisations, • Creation of roles for innovators in the organisational structure, • Energy efficiency training program for managers.
Reporting	• Ongoing briefings to senior management to maintain their support, • Public disclosure of energy performance, e.g. neighbours rating.
Facilities Management	• Organisational teams facilitated by an external energy practitioner, • In-house facilities management, • Energy efficiency training program for facilities managers.
Maintenance Contracts	• Efficiency penalties / incentives in maintenance contracts.
Planning	• 5 Year Asset Energy Improvement Plan.
Financing	• E.g. Revolving Fund to reinvest energy savings in building, • Standard Business Case Template incorporating environmental/energy efficiency benefits.

Other business practices that are positively correlated with innovation from the alternative energy supply cases studied include:

- an awareness of resource expenditure and good business case analysis practices,
- the ability to reflect across organisational boundaries and form strategic alliances with like-minded firms, and
- flexible and responsive purchasing practices .

4.2.3 The role of private and public district utility players

Governance for district utility infrastructure: in many cases transitions occur as a result of the propagation of successful business models. The principal actors identify areas that may be suitable for a particular model based on a high level perception of value that may exist. Typically, the principal will engage with a series of stakeholders to validate the opportunity.

Operating models used for district energy infrastructure have been well documented (Pierson & Seidman 2013; Portland Sustainability Institute 2011a; United Nations Environment Program et al. 2015). In particular, the United Nations Environment Program analysed international case studies across 25 exemplar cities (United Nations Environment Program et al. 2015). Internationally, much of the research on district energy business models incorporate projects that involve new precincts or look at the top down (government-initiated) approach to district energy . The following table presents a summary of the advantages and disadvantages sited in the literature of various business models with examples of each(United Nations Environment Program et al. 2015). Case studies that incorporate the retrofit of existing buildings and start as a small scheme with potential to grow into the node of a larger energy network are then investigated in more detail.

Table 14 Precinct - based business models

Model	Description	Advantages	Disadvantages	Examples
Wholly Publically Owned	The most common business model globally for district energy schemes. The public sector (local authority or public utility) has full ownership of the system. Projects have a low IRR. typically 2-6%.	Government can influence tariff structure to achieve environmental and social objectives. Ability to finance projects with government funding sources. Project transparency often leads to initiation of other private schemes. Projects with low IRR/long payback periods can still be supported.	Capital value of projects is limited especially during economic downturns. Public sector needs to be willing to take on significant project risk. Limited in house technical experience can increase technical risk.	South East Falls Creek Neighbourhood Energy Utility models on debt-to-equity ratio that would be attractive to private sector as a test case for future private sector models, VIC. Bunhill Heat and Power Company, London. Government-owned social housing and leisure facilities Beaverton Round Central Plant – Beaverton Oregon.
Privately Owned – for profit	Typically involves large private companies or multinationals owning and operating distributed energy systems for a profit. They typically receive government support if environmental and/or social objectives fulfilled.	The private sector owns the expertise to design, develop and operate systems. Some multinationals have created large pools of capital that allow them to finance projects internally without having to borrow funds on the open market.	Only support projects with high IRR (typically above 12%). Tariff may discourage investment in demand reduction activities and encourage resource consumption depending on structure.	Brewery Blocks, Portland (see case study below). Seattle Steam – Private company with a 50 year Franchise agreement with the City of Seattle.
Public Private Partnership (PPP), or Joint Venture (JV) Model	Typically, a Special Purpose Vehicle (SPV) owned jointly by the private and public sector operates and/or own the district energy system. The SPV is usually a separate legal entity with limited liability.	Risks are born by the party who has most influence on the risk e.g. public sector can manage regulatory barriers and may be able to influence customer commitment to longer-term contracts, whereas the private sector can manage the design, construction and operation risk. Access to mixed funding sources. Flexibility to buyout partners in the future.	Disputes can be avoided if parties have a clear, agreed vision of project objectives and how they will be achieved. Public sector must bare moderate risk.	Lonsdale Energy — North Vancouver, British Columbia, Canada. Southampton District Energy Scheme, UK. Birmingham District Energy Scheme, UK. Anshan District Heating, China.
Concession Contract (Private or Joint Venture)	When a government (or asset owner) allows a private organisation to operate a business within its jurisdiction, subject to conditions (e.g. revenue sharing).	The owner usually has the option to buy back the project in the future. Under the concession contract model for the private sector, the public authority typically develops a feasibility study of the district energy project and then tenders it	Contracts can be locked in for long periods. Long-term savings are difficult to guarantee.	London's Olympic Park District Heating and Cooling - a 40-year concession contract to finance, design, build and operate the network and associated energy centres. Cyberjaya District Cooling System - The city, commissioned a local energy service company (partially owned by the Malaysian Ministry of

Model	Description	Advantages	Disadvantages	Examples
	A concession model is particularly applicable for retrofit where public streets are used for network routes. Cities normally do initial feasibility studies. Mandatory connection is a feature of some district energy concession models.	to the private sector. The concession holder bears the risks of designing, building and operating the district energy system for the concession period (typically 20yrs plus).		Finance), under a build-own-operate concession, where ownership of the equipment remains with the company. University of Oklahoma with concession to Corix Utilities.
Community-Owned Not-for-Profit or Cooperative Business Model	Customers are given part ownership when they connect and share in the savings. Co-ops either reinvest any profits into infrastructure or distribute them as dividends to the owners.	The presence of the local authority can leverage low-cost funds for the project. Maximum accountability and transparency because the owners are the customers. Enables projects with low IRR to secure funds from many different owners/customers. Useful in an established area with known base load.	The local authority usually takes on significant risk initially where they underwrite project finance. Once established, risks decrease. Some risks can be passed through to third parties. Decision-making can be slow as stakeholders may have diverse interests. May lack expertise.	Texas Medical Centre Central Heating and Cooling Services Corporation (TECO). Rochester District Heating, NY. Eno, Finland Heating Cooperative. In Copenhagen, all retailers of heat are required to be not-for-profit mutules.
Business-to-Business Arrangements	Energy transactions occur directly from one business to another. Services can be provided in-house or between businesses, via a third party district energy provider.	Unlock savings from economies of scale gained by decentralised energy systems reducing the overall capital required by each party to provide energy services by centrally locating energy plant. Often avoids energy provider licencing requirements	Without an expansion plan, these systems may not expand substantially. May be complications with energy sales licences in some states	Oregon Convention Centre (see Case Study below).

Regardless of the business model, district energy business models typically involve local government support to some degree (United Nations Environment Program et al. 2015). Local governments in particular act as catalysts for change driven by public good such as sustainability and affordability. Even infrastructure that is privately controlled is likely to have benefited from some degree of public financial support, planning facilitation or other incentives. The UNEP report considers that project return on investment and the public sector's relative appetite for risk are the major determinants of business model choices observed across 45 cities globally. These business models have been tabulated below and could be used to formulate business model alternatives when establishing a new district heating scheme in an existing precinct.

Table 15 Stakeholders risk vs return appetite (UNEP)

Financial return on investment	Degree of control and risk appetite of public sector	Type of business model	Examples
Low	High	Wholly Public	• District energy to meet social objectives related to housing or fuel poverty
Medium / Low	High	Wholly Public	• Public sector demonstrating the business case of district energy systems • Public sector looking to create projects that will improve its cash flow • Public sector lowering the IRR by allowing cheaper energy tariffs than the private secotr would
Medium / High	Medium	Public / private hybrid	• Public / private joint venture • Concession contract • Community owned not for profit or cooperative
High	Medium / Low	Private (with publice facilitation)	• Private owned project with some local authority support. Perhaps through a strategic perhaps through a strategic partnership

4.2.3.1 Brewery Blocks – A Private Utility Model

The Brewery Blocks in Portland Oregon is a good example of a district cooling system which utilised the private business model. The Brewery Blocks site includes 5 blocks of historically significant properties including a brewery near the Pearl district in Portland. Purchased in 2000 by Gerding Edlen, the adaptive mixed-use re-development incorporated a district cooling scheme with central chillers on the roof of a renovated building (Portland Sustainability Institute 2011b).

The cooling system was developed and privately financed by Portland Energy Solutions, a subsidiary of Enron. No subsidies were received for the $7 million plant. Later, the system was owned and operated by Portland District Cooling Company (PDCC), an affiliate of Veolia Energy North America. Today the cooling system has grown into a small network that serves two other buildings in the Pearl District and PDCC are looking to extend their network to additional customers in the neighbourhood (EcoDistricts 2014; Pierson & Seidman 2013). There is no mandatory connection requirement to the cooling network for buildings in the Brewery Blocks area. Rates are negotiated through private long-term contracts between PDCC and its customers (Portland Sustainability Institute 2011b).

4.2.3.2 Enwave – a changing business model

The Toronto District Heating Corporation (TDHC) was originally a non-profit, publicly owned entity that combined the heat networks of local hospitals and university campuses in Toronto. However, legislation limited TDHC's access to long-term finance, impeding its ability to implement innovative solutions such as deep lake water cooling which had been investigated since 1981(United Nations Environment Program et al. 2015, p94).

As a result, TDHC was restructured into the for-profit public private partnership, Enwave Energy Corporation, with 43% city ownership and 53% ownership by BPC Penco Corporation (a subsidiary of the Ontario Municipal Employees Retirement System pension fund) (United Nations Environment Program et al. 2015, p94). The creation of Enwave has allowed the development of a deep-water cooling system that is integrated with the city's drinking water system. Enwave currently provides cooling, heating and energy management services to more than 150 buildings in downtown Toronto including commercial clients such as large banks and data centres (Gillmour & Warren 2008).

The project required a decade of continuous effort. Financial support for advanced engineering work was provided by the Department of Natural Resources Canada in the form of a grant of $1 million (half repayable) and additional private equity from shareholders for a total feasibility and engineering design cost of $3.5 million. Customers were required to sign contracts or letters of intent in order for the company to secure finance (United Nations Environment Program et al. 2015, p94). The Federation of Canadian Municipalities provided a capital works loan from the Green Municipal Fund of $10 million at market rates which has subsequently been fully repaid by Enwave (Canadian Urban Institute, Canadian District Energy Association & Toronto Atmospheric Fund 2008).

4.2.3.3 Oregon Convention Centre and Hotel – A business to business model

The central plant serving the Oregon Convention Centre (OCC) is nearing the end of its economic life and will need to be replaced 2016-17. The nearby 600 room Convention Centre Hotel development will require new boilers and chillers to provide energy services to customers in around this time-frame. Both facilities are located directly across the street from each other and, due to their respective timelines and central plant needs, represent a potential opportunity to implement district energy. The negotiation process is progressing and will include establishing a cost base line for utility services, calculating net benefits for each party and negotiating how savings will be shared. This usually requires open book accounting to give each party the required confidence in investment decisions (EcoDistricts 2014).

4.2.3.4 The Southampton District Energy Scheme – Expanding nodal development

The Southampton District Energy Scheme (SDES) began in 1986 as a public-private partnership between the Southampton City Council (SCC) and Utilicom, a French-owned energy management company. It began with one anchor customer, and grew to provide heating and cooling to over 40 public and private sector entities, as well as hundreds of domestic customers. It uses a CHP plant, geothermal energy and conventional gas-fired boilers to generate approximately 70 MW of energy (Gearty, Clark & Smith 2008; Portland Sustainability Institute 2011a).

The two parties entered into a Joint Cooperation Agreement which is summarised below (Portland Sustainability Institute 2011a).

Table 16 Agreement Summary Southampton District Energy Scheme

Southampton Geothermal Heating Company Ltd. Commitments	Southampton City Council Commitments
Develop the district heating system using the available geothermal resource.	Promote SDES to expand its customer base.
Provide management expertise to fund, install and operate the system.	Provide land for the central plant.
Provide open book accounting for long-term profit sharing with the Council.	Offer various policy and planning measures to benefit the district energy system.
Sell heat to City buildings with agreed savings.	Set up an inter-departmental working group with members from the planning, highways, housing, legal, property, regeneration and environmental policy departments to smooth approval processes

4.2.3.5 NGO Models

The not-for-profit sector can include environment, community and industry groups, driven to achieve various goals such as increasing energy efficiency, increasing employment opportunities, or improving local economic performance. This can either be done through tangible investment or awareness raising activities. Some service providers are also not-for profit, government owned organisations with a greater focus on meeting government sustainability objectives E.g. Bunhill Heat and Power Company, London.

Not-for-profit professional organisations such as AIRAH (Australian Institute of Refrigeration, Air-conditioning and Heating) are also trying to increase the uptake of sustainability practices into their membership base.

More recently, we have seen the rapid rise of the community energy model, where either private entity operates and pays dividends to a community, or a community self-organises for the purpose of purchasing power, often in a more economic and sustainable manner. The following Table 19 from (Hyams, 2010) identifies a number of options around governance of a local grid.

4.2.3.6 Energy Productivity models at a precinct scale

Models that encourage the implementation of energy demand reduction as well as the installation of alternative supply infrastructure have been less rigorously explored by the research community. In particular, demand reduction projects are rarely implemented at the precinct scale although economies of scale exist across a larger implementation area. When addressing landscape behavioural change and redirection of social norms, this strategy seems appropriate. There are benefits of operating demand reduction at the precinct scale:

- Training and information is tailored for precinct specific use,
- Relationship building can lead to greater collaboration and resource and information sharing,
- Benchmarking against similar organisations and building typologies can promote competition within the district, promoting rapid improvement.

Models have been summarised in the table below, with relevant cases examined in more detail afterward.

Table 17 Summary of Combined Demand/Supply Business Model Typologies

Model	Description	Examples
Energy Service Company or Energy Savings Company (ESCO or ESCo)	A commercial or non-profit business that offers energy services, such as energy analysis and audits, energy management, project design and implementation, maintenance and operation, monitoring and evaluation of savings, property/facility management, energy and/or equipment supply and provision of energy services (e.g. space heating, lighting). ESCOs guarantee the energy savings and/or the provision of a specified level of energy service at lower cost by taking responsibility for energy-efficiency investments or/and improved maintenance and operation of the facility. This is typically executed legally through an arrangement called 'energy performance contract' (EPC). In many cases, the ESCO's remuneration is directly tied to the energy savings achieved and guaranteed to be higher than service fees/project investments. Challenges exist around a lack of transparency calculating savings and attributing savings to projects rather than other factors such as climate or change in usage patterns (Goldman, Hopper & Osborn 2005).	For Profit – Enernoc, Buildings Alive, Cofely, etc… Not-for-Profit – Aberdeen Heat and Power Company
Bulk Precinct Retrofit Model	Utility payments from building owners are used to service debts incurred from investment in deep retrofit projects such as window and hot water system replacements. These payments are typically below current utility rates. This model is still experimental and is still dependant on significant government support.	Living City Block – US Denmark Residential Retrofit
Outsourcing facilities management	Organisations outsource the management of their buildings to an external service provider such as an ESCo or a joint venture between the external service provider and building owner. Building performance can be specified including guaranteed reductions in greenhouse gas emissions. This model has implications for precincts if one entity manages several facilities – integrated resource planning could therefore be achieved on a precinct scale. Difficulties reported include agreeing on performance, monitoring and measurement of outcomes and the loss of control of day-to-day running of assets.	University of Oklahoma University of Brighton
Bulk Purchase Agreement	Bulk purchase of energy efficiency products such as LED lighting or PV solar panels, or services such as energy and roof-top structural integrity audits allows smaller customers to benefit from wholesale/bulk rates. Prices can be significantly lower, however, system performance is not guaranteed as design may be separate to installation and operation.	Portland bulk PV purchase
Collective Model	Precinct stakeholders come together to form a collective organisation with common environmental and/or social goals. The collective envisages a desired future, measures current performance and determines strategies to move towards their collective goals. Precinct-scale projects may be funded by district resource taxes, government funding, on-bill utility payments, council parking revenues and private organisations. Typically, members are driven by a desire to be perceived as innovative and socially/environmentally aware and a belief in collective organisation.	Lloyd EcoDistrict, Portland Oregon
Membership Model	Building owners and managers receive assistance with energy efficiency retrofits in return for providing service providers with access to data or meeting council sustainability objectives. Friendly competition leads to greater uptake of energy savings projects Data gathering may lead to precinct scale infrastructure investments in the future, however, little evidence of district planning or infrastructure investment to date.	Better Building Partnership 2030 Districts

Living City Block (LCB), a US-based not-for-profit organisation, tested an innovative business model to initiate the “deep retrofit” of a city block, particularly of groups of small – medium sized commercial buildings (Living City Block 2011). LCB acts as an aggregator of individual buildings, similar to a body corporate or resource co-operative. Instead of financing retrofits themselves, building owners pay LCB for utility services, which acquires financing, procures and coordinates the retrofit work - including window replacements, water-heater replacement and smarter thermostats (Badger 2012). There is an overall decrease in utility bills to encourage building owners to join. Energy savings netted by Living City Block are then used to pay off the retrofit loans.

Initial projects were centred on Brooklyn and Denver. Failure of the model in Gowanus in Brooklyn was attributed to its low density, lack of large institutional building owners and the failure of a large building redevelopment. The legal framework, governance structures and financing were reported to be the biggest three challenges (Wells 2014). After Super-Storm Sandy however, there has been a renewed community interest in the LCB model, which has now joined with New York Eco-districts to deliver a more holistic framework for urban regeneration (Wells 2014; Badger 2012).

The University of Sussex has outsourced their facilities management services to Sussex Estates and Facilities, a partnership organisation jointly owned by the University and Interserve, a design, construction and facilities management company based in the UK. The partnership is thought to be the first of its kind in the UK.

Reasons cited for this decision include:

- The Universities’ rapid growth path, requiring considerable capacity expansion which could benefit from access to capital and expertise via a multinational partner,
- A desire for better quality services, to ensure grounds were attractive, technology in classrooms was seamless and complaints were responded to in a timely manner,
- A desire for better value for money and an understanding that getting the most out of rapidly changing technology required external expertise (University of Sussex 2015).

Part of SEF’s agreement is that SEF will work towards reducing the University’s carbon footprint by 43% from a baseline year of 2005/6, by 2020 in line with national targets for the UK higher education sector. Progress on the targets must be reported publicly and are audited by the Higher Education Funding Council for England. This reduction equates to approximately 9,000t CO2, which will be challenging as the campus seeks approval for a 17% increase in floor area as detailed in the University of Sussex Masterplan 2015 (Sussex Estates and Facilities 2015).

The implementation of the new arrangement was a difficult process for staff moving over to the new organisation and could have been improved with better communication (IST Conference Session – ProVice Chancellor Prof. Clair Makie). However, evidence exists that SEF is making progress by working collaboratively with staff and students to reassess the University’s energy policies, plans and processes. In 2015, The University of Sussex Facilities improved the Universities placing on the “People and Planet Green League” from 65th last year to 43rd. The league is an independent assessment of the sustainability of UK Universities. Although the partnership is in its early days, if successful, the model could be repeated throughout the sector in the UK.

Similarly, the University of Oklahoma entered into a 50-year utility systems concession contract with Corix Utilities in 2010. Corix manages the central heat and power plant, the chilled water plant as well as the natural gas, electricity, thermal and potable water distribution and wastewater collection networks. Corix also renews and upgrades the institution’s utility assets over the long term which remain in University ownership. Corix’s agreement with the University of Oklahoma includes the establishment of a $2 million endowment to create a new Institute for Water Resources and Sustainability at the University (Portland Sustainability Institute 2011a).

As a part of the Lloyd EcoDistrict Energy Action Plan, the Lloyd EcoDistrict working group identified an interest in a bulk solar purchase scheme (EcoDistricts 2014). Under consideration are renewable energy contracts in which a third party would install and maintain solar arrays on the rooftops of major buildings in the district. This collective approach could be a cost-effective renewable energy solution for Lloyd building owners while the scale of the deal creates the most appeal for third party investors. A recent solar energy analysis of the Lloyd EcoDistrict, completed by the National Renewable Energy Lab, estimated that 2% of annual energy demand could be satisfied through on-site solar PV installations. Also under consideration is the "Solarise Portland" bulk buying solar panel scheme which combines bulk Photo Voltaic purchase with a knowledge-sharing forum for program participants (Overdevest 2011). EcoDistricts are also organising an outright bulk purchase of LED lighting for the district.

4.3 Implementation of a district transition

Once an opportunity has been identified by stakeholders, the next phase is organising a way to implement it. The governance of a transition and thestakeholders involved depends on the approaches to procurement and the specific commercial model taken to the project.

4.3.1 Common Procurement pathways

One of the most challenging aspects of establishing district infrastructure concerns who approves the appointment of a proponent. Organisations are very well structured when it comes to procuring services for their own internal purposes. In contrast, when it comes to district infrastructure procurement processes, organisations appear to falter. There is a tension between the ideal commercial and technical structure, and what the stakeholders will approve. The more stakeholders involved, the greater the likelihood that there will be barriers.

Procurement approaches range from legislated ones, as in the case of government institutions where probity is paramount to the process, to informal business procurement approaches that are often based on trust and established relationships. The approaches to procurement are:

Table 18 Procurement pathways

Organisation	Benefits	Issues
One major local organisation (such as a University) procures a solution and then invites surrounding buildings to connect	Utilities cannot restrict the development of district infrastructure	Higher risk Still may require procurement on each building
A private company establishes a local utility, implements infrastructure and proposes solutions to surrounding buildings to connect	Private funding, may drive greater innovation and drive greater success of connections, if viable business model provides incentives	Long contracts assist system viability
A government entity establishes local utility infrastructure and proposes, or mandates surrounding buildings to connect	Governments have powers to require connection, significantly reducing business risk	May not incentivise innovation. May be subject to political cycles

In each of the above approaches, supportive legislation is critical to making a district scheme a success. A local government may, for example, implement planning regulations that mandate connection to such infrastructure.

4.3.2 Structuring the transition – commercial, legal and regulatory approach

During the procurement phase a lead entity will need to put in place a series of relationships and networks to execute on a precinct infrastructure implementation. These relationships will aim to crystallise the value for the lead proponent and will include a raft of legal, technical and commercial consultants.

At this stage of a transaction, the voice of some key stakeholders could be lost: e.g. end users of infrastructure such as students, in the case of a University. It is important that through this process there is a framework for on-going participative engagement.

The following sections outline some of the other key stakeholders in the process.

4.3.2.1 Other utility provider stakeholders

A critical part of capturing the value at a precinct level relates to the opportunities presented by arbitrage from the existing network and retail energy providers.

Pricing factors that affect viability include:

- Electricity price,
- Fuel price including gas and diesel,
- Local alternative fuel prices such as biofuels and woodchips,
- Price of green power and renewable technologies such as solar PV panels and batteries,
- Different tariff across asset classes,
- Structure or changing tariff structures including time of use, peak, network charges, etc.

Not only the average resource price but the structure of the tariff is influential for precinct scale investment decisions. For example, incentives to reduce peak yearly demand will make load shedding attractive. In Sydney, peak electricity demand coincides with peak cooling needs in the summer months so technologies such as cooling schemes and west-facing building-integrated solar PV may be cost effective if peak energy use tariffs are high enough.

To meet emissions reduction commitments, groups and organisations are experimenting with loop-holes in utility rules, directly petitioning governments for rule changes that will facilitate innovation and experimentation. One example is customer-led power purchase agreements, where the corporation buys energy directly from a renewable energy provider to avoid high network access fees and charges. These agreements are becoming common in the United States with high profile corporations like Microsoft, Apple and Google. The University of Technology Sydney (UTS)'s direct power purchase agreement (PPA) with a solar farm in Singleton owned by XYZ Solar was an Australian first. Although there is potential for precinct scale investment, collaboration between like-minded organisations within a city is more likely than within narrow precincts .

Box 5 University of Technology Sydney's Power Purchase Agreement with XYZ Solar

The University of Technology Sydney (UTS) has entered a direct power purchase agreement (PPA) with a solar farm in Singleton owned by XYZ Solar. Under this agreement, UTS effectively owns the solar farm's energy meter for billing purposes. Hence, this meter records a positive energy reading that is directly subtracted from UTS's energy bill. The arrangement is only marginally more expensive for UTS than buying power from an energy retailer.

In this agreement, UTS invests directly with the renewable energy provider – by-passing the energy retailer. Currently, energy retailers are reluctant to invest in renewable energy because there is an oversupply of electrical generation capacity on the east coast of Australia (Public Accounts Committee -Legislative Assembly of NSW 2014). Under the Australian Government's Renewable Energy Target (RET), renewable electricity is effectively treated as two separate commodities; power (which can be sold for 5c/kW) and the green part of the power which can be sold for around 4c/kW and can be used to generate Renewable Energy Certificates (RECs). The RET legislates the amount of RECs that an energy retailer has to surrender in order to meet the RET requirement.

While retailers still need RECs (i.e. there is currently an under supply in the market), an energy oversupply has meant there is little demand for new "non-green" power supply. Retailers are therefore reluctant to sign long-term power purchase agreements with new renewable energy projects as the price of any new generation is higher than continuing to use existing electricity generation. This may see them fined for not meeting the target, but at least it will not add to the oversupply, potentially prolonging low electricity prices.

The Customer Lead Renewables model utilised by UTS effectively corrects this market failure by committing to buy the "unwanted" non-green portion of the energy directly from the solar farm. The RECS will still be traded on the open market and bought by an energy retailer and used to meet their RET. Hence, because UTS do not own the RECS, they cannot claim a reduction in their carbon footprint which is a significant issue for this type of model.

UTS have stated that this agreement is an experiment. If the model proves successful, in the future, similar longer term agreements could contribute directly to new renewable infrastructure being built. Buying a small portion of a corporation's power in this way means that the entity only risks a marginal over payment for power if the energy price drops. If several corporate sponsors are pooled together, a guaranteed income to renewable energy providers could unlock finance needed to build new renewable energy generation infrastructure.

Around the globe the private sector is seeking new ways to engage with government utilities to influence policy outcomes. For example, in the US, More than Smart (MTS), a non-profit policy think tank based in California, focuses on driving energy efficiency and renewable energy policy. Currently MTS programs focus on policies that promote the upgrade of the electricity distribution grid from a uni-directional electricity flow to two-way flows that will enable integration of more solar, energy efficiency, batter storage and demand-response initiatives. MTS partners with states to plan integrated distribution grid frameworks to make their grid more flexible, transparent and efficient. MTS have developed a framework to adapt policies to local conditions. Other organisations such as EcoDistricts and 2030 Districts also seek to influence policy decisions.

Feed-in tariffs have a major impact on central energy system viability, i.e. the sale of energy generated from precinct scale technologies back to the grid. For example, the Sydney Trigeneration Master Plans are a good example of a supply scheme whose viability was inhibited by insufficient remuneration from State owned energy utilities for power sold back to the grid. Other factors that grrsupressed viability include volatile retail electricity prices, rising gas prices and a ridged energy utility structure (Jones 2014). Network customers would also be required to buy adsorption chillers, a large expenditure that would replace existing assets with residual economic life. However, resource prices are not always a driving disincentive to innovation. In Seattle and Portland, energy prices are among the lowest in the United States. Despite this, 2030 Districts and EcoDistricts have both emerged as new collaborative sustainability model, being driven by concerns over climate change mitigation and adaptation and local business striving to be smart leaders.

4.3.2.2 Financiers

It is "finance capital that judges what is "good- practice" among firms as well as among governments"

(Hawkey, Webb & Winskel 2013).

Capturing the value for a transition often means investing in significant infrastructure. End-users tend to be reluctant to invest in this infrastructure, either because they do not have the capital, or are not willing to take the risks inherent to executing a new model.

Financiers can be a key stakeholder in a transition through owning a business that is involved in a specific business model (such as Enwave). In other cases, principal stakeholders of a scheme may look to other means of raising the required funds. The following tables outline some of the models that have been used, mostly by government, to incentivise district schemes.

Table 19 Examples of financing options for smaller projects

Mechanism	Description/Example
District Tax	Lloyd EcoDistrict - Local landowners are considering paying a voluntary district tax to raise money for capital projects.
Business Improvement District	In the US, a business improvement district (BID) collects revenue through assessments on commercial property. The assessments are collected through the public tax collection mechanism. In Portland, the Lloyd Transport Management Association is funded through the BID and public-sector funding matches. The TMA employs staff that provide transit, bicycling, walking, ride-share and advocacy programs and services to Lloyd employers and employees (Portland Sustainability Institute 2011c).
Parking Benefit District	The Lloyd district in Portland gets a portion of parking meter revenues which are used to fund neighbourhood- or district- scale improvements (Portland Sustainability Institute 2011c)
Living City Block Model for neighbourhoods	Living City Block financed and installed deep energy efficiency retrofits with no upfront capital investment from the customer. Living City Block customers pay around 10% than their usual utility fees, directly to LCB. Although the model was not successful for LCB, it may have potential in a higher density commercial environment like Broadway.
On Bill Finance	Energy retailer installs equipment, paid back through a ‘repayment’ charge on energy bills. Projects can be designed to have energy cost savings that exceed the monthly payment, so consumers save energy and money at the same time, starting on day one(Office of Environment and Heritage NSW Government 2014).
Environmental Upgrade Agreement (EUA)	A loan for the environmental upgrade of a building is repaid through a local council environmental upgrade charge. For example, Central Park Trigeneration Scheme (Office of Environment and Heritage NSW Government 2014).
Green Loans	In Australia, some private financial institutions offer commercial businesses low interest green loans for energy efficiency investments.
Rebates	NSW Energy Savings Certificate Program.
Property Accessed Clean Energy (PACE) Financing	Municipal-type financing- companies issue bonds to investors and the loan proceeds are used to fund energy retrofits. The loans are repaid via owners’ property tax bills. The loan is attached to the property rather than the owners; therefore, the loan transfers with the change of ownership. The Berkley First PACE Program in California was the first of its kind to operate.
Crowd Funding	Increasingly used in community energy projects.

(Portland Sustainability Institute 2011c; United Nations Environment Program et al. 2015; Pierson & Seidman 2013)

Table 20 Financing options for larger projects

Mechanism	Description/Example
Equipment Leasing	The equipment is owned by the financier and the customer pays regular lease payments and all maintenance costs. At the end of the lease, the customer has the option of returning the equipment, making an offer to buy it, or continuing to lease it (Office of Environment and Heritage NSW Government 2014).
Energy Performance Contract	A specialized energy efficiency retrofit contractor, such as an ESCO, finances the investment, guaranteeing future energy performance and recovering capital directly from the energy savings generated by the retrofit, some of which are often shared with the building’s owner as an incentive to reduce costs (Sweatman 2010).
Debt provision and bond	Cities can issue bonds to generate revenue for projects. Enwave used revenue and

Mechanism	Description/Example
financing,	general obligation bonds issued by the city of Toronto to raise capital for its deep-water lake cooling system. To secure the financing for the project, the city required future customers to sign contracts or letters of intent.
Public Asset Provision	Seoul has supported the construction of fuel cell combined heat and power plants – some on city-owned land.
Loan guarantees and underwriting	In the U.K., the Aberdeen City Council underwrites (via a loan guarantee) the not-for-profit district heating company, allowing it to obtain commercial debt financing at attractive rates.
Local Governmnet Grants	The City of London has provided development grants for early-stage feasibility assessments and investment-grade audits.

4.4 Operational phase of a transition

During the operational phase a long term structure must be put in place to govern the process and ensure effective operatoin and risk management. This is often the hardest phase of the transition as commercial interests have to be protected while investigations are carried out. There are also risks of pricing and infrastructure being shut down which undermine owner, asset manager or investor confidence.

4.5 Governance and access to data

During this research, it became clear that a major barrier to successful transitions concerns governance. In order to obtain a meaningful and usable set of metrics that form a baseline for future decision-making, we first needed to assess the data complexity and its relevance to precinct wide decision making. We also needed to consider the validity and accuracy of the data received from a number of different stakeholders and sources to understand and highlight limitations and gaps in its use. This data story addresses these questions and seeks to influence recommendations for the future.

The potential range and breadth of data available at a precinct level can be extensive, so it important to consider the project goals when prioritising data selection. Time and resources are often limited and so various data sources provide only top level data, and incomplete data sets. Most critically perhaps, we found that confidentiality of the data represents a significant hurdle to meaningful research outcomes at a precinct level.

In the early planning stage, the research team decided to focus on top level data and dig in to selected data sets where relevant and beneficial, thus capturing an optimal baseline of sufficient quality and quantity as highlighted in Figure 16. An example of this is with asset data captured during the research, choosing to include individual asset locations, replacement, maintenance and energy loads where information was readily available, but excluding resource intensive monitoring of asset utilisation.

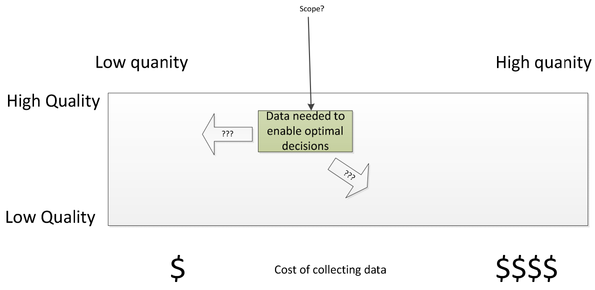


Figure 15 Optimal Data Capture

The future value or worth of the data received and its ability to influence future policy and governance decision-making is important to consider, however difficult to determine. Data sets may appear of high quality and quantity; however it is only when variables in the data sets are explored in-depth that the accuracy of the data can be validated or their appropriateness determined.

To enable effective decision-making on energy and water systems at a precinct scale, however, some very basic information around supply, demand and distribution is required. The resolution of this data needed to enable effective decisions hinges on the stakeholders' needs, the key economic drivers and the governance or business systems available. There are also significant variances in the ownership of this information, the transparency, accuracy and the ability to relate it to other data sets to enable effective decisions.

Supply / Demand benchmarks

The tables below outline some of the different potential sources of demand / supply data for utilities and some of the pros and cons of capturing and using energy and water data. This has been adapted from some research completed by Greensense in 2015:

Table 21 Account or Billing Data

Resources covered	Electricity, water and gas
Sources	Utility invoices. Landlord invoices, if your site sits within an embedded network. Your energy broker, if you use one.
Formats	Paper bill or electronic PDF file. Some retailers will provide an Excel file of all your accounts if you are a large customer, however there can be restrictions on its supply or use.
Data Quality	Depends on how the meter is read. This can be problematic if you are part of an embedded network, where the meter reading process is often manual.
Pros	Useful for long term trending and reporting for property and environmental teams and, for the finance stakeholders, good for bill validation when crossed-checked against interval data and your tariffs (see below).
Cons	This type of data is too coarse to be used to detect performance outliers, such as a building running its HVAC system through a public holiday. Also, accessing and collating this type of data can be time consuming, particularly where multiple suppliers are involved.

Greensense, 2015

Table 22 "Day behind" interval data for electricity

Resources covered	Electricity
Sources	Your Meter Data Provider (MDP), if you are based within the National Energy Market (NEM) and you have the correct meter type. If you are in Western Australia, then Western Power offer a similar data feed on a weekly or monthly basis. To find out who your MDP is, contact your energy retailer. For more info on MDPs check out this link.
Formats	Typically provided as a csv file in NEM12 format,
Data Quality	High. The MDPs have processes in place to ensure meter data is complete and accurate.
Pros	Bill validation – when you apply your energy tariff to this form of data you can generate a "shadow bill" to compare to the one you got from your utility provider. Ongoing performance management – interval data, and the ability to automate its ongoing collection and processing, make it a good starting point for identifying efficiency opportunities. Measurement and verification of efficiency projects and building upgrades. Because this approach leverages the existing metering reading process, no additional hardware or site visits are required.
Cons	Given the data is from your main meter, identifying the specific loads that are causing efficiency issues is difficult. You may need sub-metering for that. Depending on the size and geographic spread of your building portfolio, you may have to liaise with several MDPs.

Greensense, 2015

Table 23 "Day behind" interval data for water and gas

Resources covered	Water and gas
Sources	Data logger attached to your main water and gas meter.
Formats	Depends on the data logger but typically csv files or a web service.
Data Quality	Good, if the loggers are installed and maintained correctly. Consideration needs to be given to things like 3G network coverage.
Pros	Good for leak detection and general performance monitoring.
Cons	Requires the purchase, installation and ongoing maintenance of some logging hardware. In the case of gas meters you'll also need to get permission from your gas network operator before connecting up any monitoring hardware to the meter.

Table 24 Near real-time data (electricity)

Resources covered	Electricity
Sources	Typically you will need to install some additional logging hardware, however some MDPs are now beginning to offer a near real-time service in response to growing interest in demand response/management.
Formats	Typically csv files or a web service.
Data Quality	Pretty good if the loggers are installed and maintained correctly, although the nature of real-time data does make it more susceptible to transient issues like brief communications outages.
Pros	Critical component of demand response programs. Identifies operational issues as they occur. Good for educating and engaging building occupants around energy use. Nobody finds old, stale data interesting.
Cons	Can have higher costs both to set up and to maintain. Generates significant data. You need to know what you need it for.

Greensense, 2015

Table 25 Sub-meter Data

Resources covered	Electricity, Water and gas
Sources	Building Management System (BMS) – many metering networks will feed data into the BMS, where it often remains, ignored and unloved. The good news is that, with a bit of work with your BMS contractor, you can normally get access to it. Gateway Hardware – if you have a metering network that isn't connected to the BMS, then you will need a gateway device. This is a piece of hardware that is physically connected to the metering network, reads the meters on an ongoing basis and then makes that data available to other systems, often in the form of a csv file export. Manual meter reading. Not much to say here. If you are unlucky enough to only have manually read meters, then you can expect the data to come through to you once a month or thereabouts, probably as an Excel file.
Formats	Depends on the data source and ranges from Excel files through to sophisticated web services.
Data Quality	Can be very variable depending on how well the sub-metering network was installed, commissioned and maintained.
Pros	Provides a level of insight into building performance that is simply not possible to get from your utility meter.
Cons	The installation of sub-metering can be expensive and, particularly in older buildings, quick complex. Generates lots of data which can be overwhelming if you don't have the right tools and experience to handle it.

Greensense, 2015

4.6 Summary

In the previous section we have attempted to give an overview of governance success factors at each stage of a precinct transition. These factors have been summarised below and will be used to draw conclusions relating to the Broadway precinct.

Table 26 Governance Barriers and opportunities

Factor	Barriers	Opportunities
Governance Structures	No existing precinct structures, practices, etc.	More innovative structures and practices can evolve that deviate from business as usual.
Stakeholders	Multiple stakeholders with various interests leading to complexity and potentially dispute.	Stakeholders can combine skills to identify and capture value using in-depth knowledge of local issues.
Relationship	Trust and interdependence.	Alignment of values creates firm collaborative relationships
Regulatory	Changing energy sector means business models are open to considerable risk – as rule changes are likely within the 20 year investment horizon.	Business models need to consider a wide variety of future scenarios. Carbon pricing or similar policies likely in the next decade.
Energy Price Fluctuations	Projects will continue to be vulnerable to energy price fluctuations.	Collaborations allow partners who have the greatest ability to mitigate risks to be responsible for them.
Utility	Currently present significant access cost hurdles.	Access barriers are being challenged by local government and academics. Progressive utilities stand to gain market share.
Business models	More complex as number of stakeholders increase resulting in significant legal costs.	Open book negotiations can lead to innovative models that improve project viability.
Finance	Difficult to finance using traditional sources.	Increasing evolution of innovative finance mechanisms. Partnering with government may allow access to government infrastructure funds.
Economic	Significant capital barriers to infrastructure investment, short pay backs required by precinct businesses, large transaction costs where district infrastructure is new.	Organisations benefit from being identified as green, socially aware, innovative and future focused. Sharing infrastructure to minimise operating costs, free up land and reduce maintenance costs.
Data	Accessing data can be time consuming and complex at a precinct scale and, most importantly, it can present confidentiality limitations.	A data tool that enables private sharing of data where stakeholders could control and authorise data-sharing may provide significant benefits.

5.0 Broadway Precinct, Sydney

The mission is to identify and understand the economic, stakeholder, regulatory and technical barriers to transitioning Broadway precinct to low carbon energy and water solutions and devise viable pathways for stakeholders to successfully transition. Key objectives of the research are to create mechanisms that enable a precinct to be informed, organised and empowered to create a successful low carbon water and energy transition. The desired objectives from all phases of the research will be to:

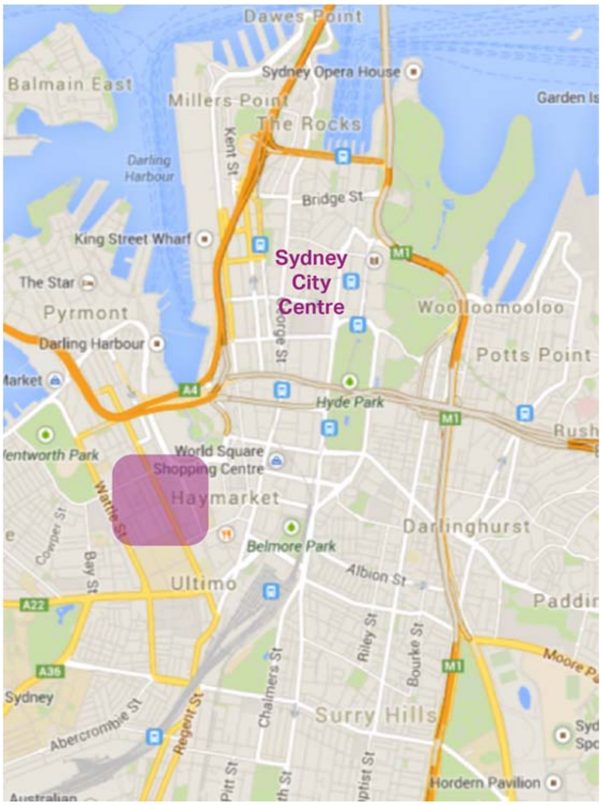
- Enable a transition of the Broadway Precinct towards a low carbon outcome,
- Provide publicly available guidance and knowledge to stimulate the market for the low carbon retrofit of precincts,
- Create a low carbon transition management toolkit that will empower future precincts in Australia to reduce carbon intensity,
- Use research to demonstrate and evaluate the economic, social and environmental co-benefits of a low carbon transition,
- Clearly articulate the appropriate policy and regulatory requirements to enable precinct scale solutions.

5.1 Introduction

5.1.1 Broadway Precinct

In 2014, a number of industry members of the CRC for Low Carbon Living sought out an existing precinct with stakeholder drivers aligned with transitioning towards a low carbon future. Broadway precinct in Sydney was identified as an ideal location to initiate research for a precinct scale transition with multiple, informed and driven stakeholders across a range of assets with different ages and uses. With Brookfield, City of Sydney and TAFE all members of the CRC and all stakeholders within Broadway, this area was identified as an ideal research basis for investigating and possibly enabling a precinct transition.

The precinct evolved to included Central Park (Brookfield as the facilities manager), University of Technology Sydney (UTS) Ultimo Campus and Sydney Institute of TAFE. The following maps provide the location of the study area.



LOW CARBON LIVING CRC

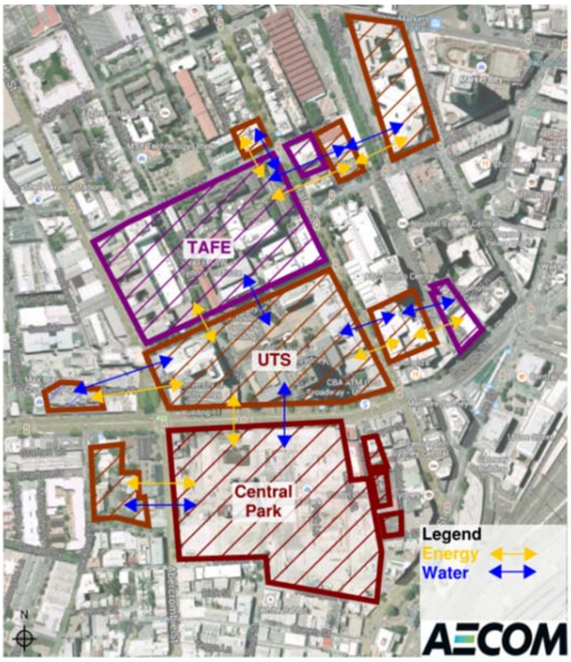


Figure 16 Empowering Broadway Research Precinct Location

The Broadway precinct includes a broad range of buildings starting with buildings from the late 1800's within Sydney Institute through to buildings like Chau Chak, within UTS, which is a modern 5 Star Rated building with a 20,000 litre water tank. The precinct also includes a land use mix across educational, commercial, residential and retail uses that provision a diversity of users.

Each of the four key stakeholders have different interests and motivations to see Broadway emerge as a more sustainable precinct. The City of Sydney has energy and water master plans which identify significant opportunities for precinct retrofitting but need stakeholders' involvement and sets significant carbon and water reduction targets across the LGA. TAFE and UTS already operate their campuses as precincts seeking optimal efficiencies from a cross building approach to asset management and utilities provision seeking carbon reductions, where possible. They also have organisational commitments to carbon and water reductions. Central Park has been held up as a case study for energy, carbon and water transitions through adopting a precinct scale trigeneration system and water treatment facility providing much of the energy and water needs though alternative supply.

5.1.2 Sydney Institute (TAFE)

TAFE operates a campus to the north of the study area with 19 buildings which vary in age, use and efficiency. TAFE provides tertiary education across 700 separate courses. As an Institute it celebrated 120 years in operation in 2011. There is a facilities management team that take on separate responsibilities across the campus however there are a number of efficiencies that have been realised through collaborating asset and building management across the precinct. The following map identifies the TAFE site and buildings.

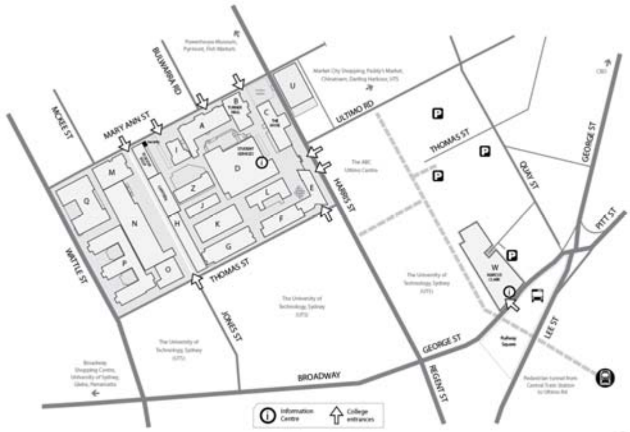


Figure 17 Sydney Institute buildings map

UTS

UTS operates a central campus in the middle of the study area with a number of smaller clusters of buildings located to the north and south of the core central campus. UTS provides tertiary education. Many of the university buildings are older style buildings with varying efficiencies as well as a number of new, more efficient, buildings that have been recently completed four of which are Green Star Rated. The University runs a centralised plant in CB01 and a thermal distribution network that connects most of the campus buildings.

Newer buildings have been designed with a number of sustainable features including rainwater capture and reuse and renewable energy provisions. The campus is installed with a 22kWp PV system consisting of 72 modules, a 12kW vertical axis wind turbine and parabolic solar concentrators generating 60MWh of thermal energy.

Figure 18 UTS buildings map

5.1.3 Central Park

The Central Park development has become one of the world's most recognised examples of sustainable building and infrastructure planning with over 30 of awards received to date (Central Park Awards). It has also become the focus of a large range of industry and academic research projects seeking examples from the development with almost constant tours of the site including the green walls, water treatment and tri-generation facilities.

Central park is still continuing development and currently includes over 1500 residences, major shopping centre (65,000 m2) and three retail precincts, dining and entertainment, commercial campus and a major new public parkland. The development ranges between 8 and 34 stories and includes over 150,000m2 of Gross Floor Area and a landscaped area of around 64,000m2 (including the vertical gardens).

From a sustainability perspective the development has achieved multiple 5 Star Green Star – Multi Unit Residential v1 Design Ratings and a 5 Star Green Star – Retail Centre v1 Design Rating. The developments are yet to finalise their As Built ratings. As well as integrating energy efficiency measures within the apartments and retail uses the development includes a 30MW central thermal plant, a 2MW tri-generation system and a 1ML per day black water treatment plant. It has also included extensive use of Green Walls and Heliostat reflectors to enhance the design and amenity.

Figure 19 Central Park 3D master plan

Figure 20 Central Park 3D master plan

5.2 Broadway Precinct Baseline

Of the Phase 1 research provided bas2line information for the Broadway Precinct to enable further development of case studies and research to determine optimal pathways for transition drawing on a sound existing context. This sought to understand the existing stakeholders and their drivers, the governance structures in place as well as the energy and water assets and utilities consumption profiles. This section provides some of that baseline information.

5.2.1 Stakeholders (Flow)

Identifying key stakeholders is a significant element to this strategy's implementation. The first task was to identify the key stakeholders that control, influence or consume the energy, carbon and water within the precinct. In considering these stakeholders the following criterion was adopted:

- **Direct influence** – Stakeholders with influence or decision-making power over the consumption or assets within the study area (Owners, tenants, facilities managers)
- **Responsibility** – Stakeholders who consume energy or water within the study area (Individual consumers)
- **Representation** – Through regulation, custom, or culture the stakeholder can legitimately claim to represent a body or client (Agents)
- **Policy and strategic intent** – Those who can impact energy or water systems directly or indirectly through policy, practice or research (Government or business)

Following the identification of key stakeholders an assessment was undertaken to identify action responses. This assessment included the following:

- Key issues, concerns, perspective
- How supportive
- How affected
- How influential

The action responses to the assessments covered the following criteria:

- How will they be engaged
- When will they be engaged
- Who is responsible

This is to identify those that may be key to a precinct transition and how they have or will be engaged.

The following table describes the key stakeholders for the Broadway Precinct and assesses their level of interest, influence, interrelationships and engagement.

The following table describes the key stakeholders for the Broadway Precinct and assesses their level of interest, influence, interrelationships and engagement.

Table 27

Stakeholders	Description	Interest	Importance/ Influence	Key relationships with other stakeholders	How have they been engaged to date
City of Sydney	Relevant local council.	Provides vision, targets, goals and regulations. Owns and controls public domain infrastructure Facilitation and incentives and upgrade agreements.	High	Collects rates, provides services, provides leadership and reflection of community values and ethics.	Engaged from inception. CRC LCL member. Project signatory. Facilitated BBP engagement. Engaged in 3 project workshops. Provided in kind investment into research.
Utility Infrastructure users	The users of infrastructure include residential tenants, commercial building tenants and retail tenants.	Lower energy bills, reliability, safety, environmental outcomes, star ratings (particularly commercial tenants).	High - Influences long term revenue stream of utility infrastructure owner which underpins investments. Direct impact on carbon intensity through behaviour.	Financial relationship with building owners. Operational relationship with facilities managers. Strata fees may include some element of utility costs.	Have not been engaged to date. If a behaviour change program is coordinated at precinct scale they may be engaged.
Building owners	Owners of buildings are a diverse group characterised by how actively or passively they manage assets and their individual drivers.	Increased yield, building ratings (NABERS), asset value and performance.	Very High - Building owners critically influence the adoption of district schemes.	Financial relationship with infrastructure users.	Limited engagement to date. Would seek input at transition phase.

Stakeholders	Description	Interest	Importance/ Influence	Key relationships with other stakeholders	How have they been engaged to date
Local building / precinct infrastructure (Facility) managers	Facilities managers are either employees of business owners or of specialist facility management companies. In Broadway their roles range between individual building to building clusters or asset classes.	Higher performing buildings, simplified management systems, job security.	Mid/High	Facility managers influence building owners and users and provide building utility and asset information.	Engaged to date through targeted meetings and Better Building Partnership.
Local utility infrastructure owners	Private companies that would run position to the local utility infrastructure. Companies often distribute medium or low voltage as well as local thermal networks.	Commercial interest in providing a local utility service for the micro grid.	Mid	Wins concessions from building owners to provide services to users in collaboration with Facility managers.	Brookfield / Flow are one of the project partners and control local utilities at Central Park. Operate commercial systems that are subject to confidentiality and contractual terms.
Electricity distribution services companies	Companies (such as Ausgrid in Sydney) who distribute High, Medium voltage through the city of Sydney.	Customer safety security, pricing, economic return on assets.	High	Influence regulatory position on how local networks can make money.	Engaged as supplier
Electricity transmission services companies	Transmission organisations such as TransGrid, own and operate high voltage transmission networks.	Are interested in the long term impact of loads within Sydney on their investment decisions.	Low	May provide funding if the project is seen as having significant network benefits.	Not engaged
Gas distribution companies	Gas distributors such as Jemena provide wholesale gas services.	Selling gas, seeking return on assets	High	Influence the economics of local service provision.	As supplier
Water distribution and retailing	Sydney Water is the dominant distribution and water retail provider within the precinct. Flow Systems is the	Selling water and seeking return on investment. Carbon intensity of water is not the	High	Influence the economics of local service provision.	As supplier

Stakeholders	Description	Interest	Importance/ Influence	Key relationships with other stakeholders	How have they been engaged to date
	distributer and retailer for the Central Park project.	primary focus.			
Related technology providers	Companies that bring skills and expertise around how to implement and run local energy networks. Software, hardware and other intellectual property. Each building runs a different Building Management System (BMS) or Energy Management system(EMS) with varying data logs and data quality.	Interest in controlling and setting the data and technology standard. Interest in selling technology services.	Low/Mix	Vendor to local utility infrastructure companies.	Need to be engaged around data standards and data sharing.
Related consultants	Environmental, design, energy efficiency consultants. UTS, WSP, AECOM, ARUP and others have been engaged to consider elements of the sustainability, energy and water profiles and design within the study area.	Provide advice to stakeholders and provide thought leadership.	Low/Mid	Contracted to the various local stakeholders.	Have provided reports.
Energy market regulators	Organisations such as AER and AEMO.	Provide regulatory framework under which local networks operate.	High	Regulatory body.	Provides information to stakeholders
NSW Government Treasury	State government funding entity.	Provides funding to state owned corporations that deliver network services.	Mid	Can provide funding for alternative infrastructures where proven to be beneficial over business as usual.	Not engaged
NSW Environment and Heritage	State government department charged with environmental protection.	Works to protect and conserve NSW environment working with other stakeholders.	Low	Can provide small grants. Can provide policy support and access to government.	Not engaged
Federal Government Department of the Environment	Federal government agency charged environmental protection.	Works to implement and manage federal policies that impact the environment.	High	Can provide policy direction around carbon abatement.	Not engaged
Educators	Local universities and schools. Many courses have relevant subjects looking at energy, carbon and water as well as	Learn relevant skills to students. Provide a living laboratory for students to draw from and	Low/Mid	Have an interest in engaging where a local program can provide skills	Are aware of initiatives and want to be engaged.

Stakeholders	Description	Interest	Importance/ Influence	Key relationships with other stakeholders	How have they been engaged to date
	governance, business and technology which may be valuable in enabling transitions.	investigate.		and/or work to students.	
Students	Local students (there are approximately 50,000 students in the area)..	Obtaining a degree to further careers and/or obtain knowledge.	Low/Mid	Work with teachers, pay fees to universities	Not engaged
Other local groups	Other local environmental initiatives such as "Smart Local " which is focused on wider transition initiatives around water, waste and social change.	Driving environmental change within Broadway.	Low/Mid	Engagement and awareness.	Not engaged
Local workers	Workers in businesses in the region (approximately 26,000) * Smart local	Various interests and varying degrees of engagement in environmental issues	Low/Mid	Work in buildings owned by building owners.	Not engaged
Local residents	Residents who live in the Broadway area (approximately 18,000).	Cost effective living. Varying degrees of engagement with environmental issues. Thermal comfort and supply certainty.	Low/Mid	Live in buildings, provide rates to council, vote in councillors.	Not engaged

5.1 Utilities and asset data

Whilst it would be useful to have a vast array of data to analyse and evaluate, there are both restrictions with data availability and the time it takes to source and/or generate this data. As a result, a targeted approach has been adopted for the purposes of this Phase 1 study. With the overarching aim to provide a relevant and useable set of data to inform stakeholders of current energy, water and asset performance, the following scope has been targeted:

- Buildings/campuses- All TAFE, UTS and Central Park buildings within the immediate Broadway Precinct have been considered for the development of baseline data. Where the relevant data is difficult to come by, the provision of larger buildings data will be prioritised to account for a greater proportion of the precincts overall footprint.
- Gross Floor Area (GFA)- Gross Floor Area has been captured to identify the buildings average energy, water and asset use per m2.
- Metered data- Both mains metered and sub-metered energy and water data to all buildings within the immediate precinct has been earmarked for capture. This will ideally provide both an overview (mains metered data) and a building/room/activity specific view (sub-metered data) of water and energy use throughout the precinct. Meter readings from the 2015 calendar year will typically be used.
- Tri-generation, cogeneration and renewables - Energy input and output from tri-generation and cogeneration plant and renewable energy sources will be captured where available to provide specific plan /asset case studies.
- Building profiles- Measured demand will be captured using ‘real time’ energy provider and metered data where available. Building profiles from the AECOM SSIM model may also need to be used where gaps exist to develop consumption against industry modelled averages.
- Occupancy/use- Buildings/room use data will enable user comparisons against energy, water and asset data.
- Assets- Expected maintenance and replacement dates will provide an insight into anticipated future procurement cost and timings and opportunities to consolidate these. Targeted assets replacement schedules will be typically for the next 30 years.

The above scope identifies the targeted data to be captured, however there are a number of limitations to obtaining a meaningful set of data that can centrally collected and compare.

5.3.1 Information Requests

Obtaining the relevant pieces of information in a vast array of documentation and records can be challenging, with the interpretation of multiple data types in multiple formats even more so. To tackle this, the project team developed and circulated an Information Request Form to identify which sources of information were available to the research team. Individual meetings were held with each of the study stakeholders and suggestions for information capture recorded for future reference. The questions provided to stakeholders are outlined in the information request form. The request was firstly on the existence of the data, the availability of the data for the research project and any issues or barriers in the provision of the data. The stakeholder responses are provided in the Appendix.

Table 28 Information Request Questions

General precinct questions
Do you have a Masterplan? Is it available in digital format? Is it available in 3d?
Do you have an Infrastructure Servicing Strategy? Is it available in digital format? Is it available in 3d?
Do you have any studies on efficiency potential or alternative supply within your precinct or connection to other owners within the wider precinct?
Asset questions
Do you have a full asset database and management plan?
Do you have a replacement schedule for building and precinct assets?
Do you have a building attribute asset schedule identifying façade quality, orientation, age etc?
Utilities / consumption questions
Can you provide data on **energy** generated or consumed within the precinct? • Type – Electricity / gas. And if possible down to electrical, thermal and mechanical. Including cost where possible. • Scale - Consumption rate per sqm (based on GFA > NLA > Tenant > Use > or to as fine a grain as possible) • Time of use - Consider 24 hr cycles, seasonal cycles and annual (for peak scaling and infrastructure matching)
Can you provide data on **water** consumption within the precinct? • Type - potable, non potable, stormwater and waste, including cost where possible. • Scale - Consumption rate per sqm (based on GFA > NLA > Tenant > Use > or item to as fine a grain as possible) • Time – time of use if possible (for peak scaling and infrastructure matching)

5.3.2 Limitations and Alternatives

A number of limiting factors provided a barrier to the collection and analysis of usable data sets available to the research team. Where available, alternatives to the originally proposed data sources were utilised to provide the most complete set of data possible. Limitations to capturing usable information from stakeholders included:

- Availability - Information originally earmarked for collection in Information Request Forms that was subsequently not available for provision to the research team. This was either to do with data quality, source or commercial sensitivities.
- Fragmentation - Data collected in multiple forms making collation amongst data sets and stakeholders difficult.
- Transparency/Accuracy - Data collected may have come from a questionable source or is unsubstantiated e.g. an uncalibrated meter reading.
- Age/Relevance - Asset schedules provided ranged from 10 years to 30 years
- Detail- Asset registers provided varying degrees of detail with some stakeholders highlighting replacement years, whilst others were unknown.

The following table provides the data capture story for the three precinct stakeholders.

Table 29 Captured data, source comments and

Stakeholder	Data type	Source	Comment	Recommendation
UTS	EMS sub-metered data	Centralised supply of energy including CB01 central energy thermal plant providing CB02 and CB03	Unable to capture energy used and cost per building	Additional studies to be undertaken to 'ring fence' and model buildings energy use.
	Billed energy data	Centralised mains supply of gas and electricity	Mains meter readings are not separated for each building	Further development of EMS and installation of sub-metering
	EMS sub-metered data	Accuracy of data due to maintenance and reliability of systems	Unable to provide accurate historical data for all sub-meters	For the purposes of this report, Ausgrid mains meter readings were used for electrical consumption to increase data reliability. Gas, water and thermal consumption/production was captured using the EMS system. In some cases sub-meters had gaps/inaccuracies in data. Reliability of this system should be explored further for appropriateness in decision making. Manual meter readings (currently once every 3 months) help validate sub-meter readings.
	Thermal sub-meter readings	Only partially installed/newly installed system	Data/gaps in thermal system historical data making it difficult to accurately measure central thermal plant output and energy consumption per building or area	Further installation of new meters and calibration of existing ones. Additional studies to be undertaken to 'ring fence' buildings energy use.
	EMS sub-metered data	Understanding/Interpretation of elaborate utility network	Difficulty defining energy used and produced using EMS	Renaming some meters installed on the EMS system to clearly demonstrate energy consumed and produced and interconnectivity between buildings
TAFE	Mains energy data	Mains records dated 2011	Data obtained not current. Unable to understand energy per building/asset	Obtain current bill data to allow for more informed decision making
	Mains Water data	Water consumption recorded not covering a full calendar year	Estimated annual water consumed using data from 19/2/2015-20/8/2015	Obtain annual water usage using 2015 billed readings
	Mains data	No water costs provided. No breakdown in costs provided for energy consumed.	Cost estimations made using industry pricing	Obtain a breakdown of water and energy costs
	Assets	Traffic light system used to determine maintenance/replacement dates	No exact timings provided for maintenance/replacement of assets	Further inspection and estimation of asset replacement/maintenance lifecycles

Stakeholder	Data type	Source	Comment	Recommendation
Central Park	GFA	GFA of current buildings sourced from construction documentation.	Data accuracy uncertain	Seek as built GFA and NLA from Frazers.
	Utilities	Private tenants bills not available. Retail tenant bills not available. Energy profile from thermal network not available.	Commercial sensitivities over data restricted data availability from Central Park.	Model based on industry standards for BASIX apartments, Seek separate case studies or Green Star certification documentation.
	Assets	Published papers on Central Park provided basic specifications for the thermal, tri-generation and water networks.	Only the size of the plant known. Further information	Further information would need to be sought from Brookfield on assets.

5.3.3 UTS

5.3.3.1 GFA, Water and Energy

Gross Floor Area (GFA) and Usable Floor Area (UFA) were sourced from the Tertiary Education Facilities Management Association (TEFMA) 2015 survey. This provided a comprehensive account of all major UTS Broadway and Haymarket campus buildings.

Table 30 UTS Buildings and GFA.

Building number	Name	GFA
CB01	Tower, Building 1	62498
CB02	Building 2	24063
CB03	Bon Marche, Building 3	6725
CB04	Building 4, Science	30516
CB05	Haymarket, Building 5	35515
CB06	Peter Johnson Building, Building 6	29605
CB07	Building 7 (Faculty of sciecne and graduate school of health building)	20136
CB08	Dr Chau Chak Wing Building, Building 8	18450
CB09	The Loft	205
CB10	Buidling 10	44948
CB11	Building 11 (FEIT Building)	45583

The range of water and energy data on offer from UTS' EMS system was extensive. The EMS provided a range of electrical, gas, thermal and water sub-meter readings using both real time data and historical reports. In most cases these reports were able to be generated by building or by individual utility except where central meter readings had been used for enhanced accuracy.

Instead of answering questions around the energy and water consumed and produced, evaluation of the EMS led to further questions being asked. These mainly focused on the interchangeable relationship of energy used between each building within the UTS Broadway and Haymarket precincts. CB01 was a prime example with a central thermal plant supplying hot and cold water to a number of the other buildings in the precinct. This created difficulties ring fencing buildings energy use, with gas use in particular prevalent in CB01 due to the aforementioned.

Electrical sub-metered data was unable to be used due to gaps in data throughout 2015. Instead Ausgrid mains metered readings were used a more accurate measure of buildings electrical consumption. As highlighted inTable 31, these created issues ring fencing electrical consumption in CB01, CB02 and CB03 as all three were centrally metered in CB01. Annual data sets for renewables were unable to be obtained due to intermittent usage and a lack of connectivity to the wider EMS system, so an isolated 5 day meter reading was used to estimate annual electrical generation from PV panels on the CB07 rooftop, equating to an estimated 18 MWh per annum.

Table 31 UTS Energy Use and GHG Emissions, 2015

Building	Location	Energy			$t\ CO_2e$ per annum		
		Electrical Grid (kWh)	Gas (m3)	Gas (MJ)	Electricity	Gas	TOTAL GHG
CB01	Tower, Building 1 (Including central plant)	20058097.99*	24285367.60*	915101793.61*	16848.80231*	47036232.19*	47053.08099*
CB02	Building 2	0.00*	0.00*	0.00*	0*	0*	0*
CB03	Bon Marche, Building 3	0.00*	0.00*	0.00*	0*	0*	0*
CB04	Building 4, Science	5580498.12	39336.28	1482238.23	4687.618422	76187.04522	80.87466365
CB05	Haymarket, Building 5	5851989.82	502057.59	18918132.46	4915.671452	972392.0085	977.3076799
CB06	Peter Johnson Building, Building 6	2620186.29	0.00	0.00	2200.956483	0	2.200956483
CB07	Building 7 (Faculty of sciecne and graduate school of health building)	1979620.06	47281.72	1781631.95	1662.880847	91575.88211	93.23876296
CB08	Dr Chau Chak Wing Building, Building 8	2355469.70	28112.00	1059293.89	1978.594548	54447.70617	56.42630072
CB09	The Loft	0.00*	0.00	0.00	0	0	0
CB10	Buidling 10	6775657.48	65934.00	2484472.24	5691.552283	127701.8732	133.3934255
CB11	Building 11 (FEIT Building)	7611733.87	29435.40	1109161.19	6393.856447	57010.8854	63.40474184

**NB: Building specific energy use in CB02 and CB03 is centrally metered as part of CB01 meter readings.*

Sub-meter readings in the EMS for water consumption again highlighted the centralised consumption in the CB01 central thermal plant and gaps in sub-metering data in CB03 and CB04. The data included recycled water usage in both the new built Chau Chak building (CB08) and the Faculty of Science and Graduate School of Health Building, however it appears not all recycled water used had indeed been captured including water recycled from the bleeding of chillers in CB01.

Table 32 UTS Water Use, 2015

Building	Location	Potable Water Used (ML)	Recycled Water Used (ML)	Recycled Water Source	Recycled Water (%)
CB01	Tower, Building 1	140.10	0.00		
CB02	Building 2	4.38	0.00		
CB03	Bon Marche, Building 3	0.00	0.00		
CB04	Building 4, Science	13.69	0.00		
CB05	Haymarket, Building 5	20.31	0.00		
CB06	Peter Johnson Building, Building 6	17.77	0.00		
CB07	Building 7 (Faculty of science and graduate school of health building)	19.48	10.79	Rainwater tanks	35.65%
CB08	Dr Chau Chak Wing Building, Building 8	3.33	56.37	Rainwater tanks	94.42%
CB09	The Loft	0.00	0.00		
CB10	Buidling 10	23.84	0.00		
CB11	Building 11 (FEIT Building)	101.53	0.00		

After consultation with the UTS sustainability team, it was understood that thermal meter readings had also been installed in the buildings. These thermal meter readings for 2015 have been included in the UTS data set for completeness although are not comprehensive due to the relatively new installation of equipment and complex nature of measuring thermal energy increasing the potential for errors.

One of the challenges with interpreting and standardising meaningful data sets was with the complex interconnectivity of buildings utilities. UTS provided a utilities road map to help further understand and identify the relationship between each building.

5.3.3.2 UTS Assets

UTS provided a detailed asset register including chillers, a/c units, cooling towers and boilers. A replacement and maintenance register was provided detailing nominal replacement dates up to 2035 as well as estimated costs involved with replacement. A number of assets were earmarked for replacement at the same time, highlighting opportunities for bulk procurement in the future. Nominal capacities (kW), nominal refrigerant charges and refrigerant gas types were all provided for each asset.

5.3.4 TAFE

5.3.4.1 TAFE GFA, Water and Energy

GFA was sourced from an internal site accommodation summary report provided by TAFE that accounted for all major TAFE buildings in the Broadway precinct.

TAFE was unable to supply EMS data for each of its buildings; instead a Level 2 Energy Audit Report (2011) was used for annual energy and gas readings and a Water and Waste Efficiency Assessment (2015) used to demonstrate annual water use. No thermal modelled or actual metered data was available.

Table 33 TAFE Energy Use and GHG Emissions, 2011

Stakeholder	Building	Electrical Grid (kWh)	Gas (m3)	Gas (MJ)	t CO_2e per annum	
					Electricity	Gas
TAFE	A	565.04	15509.12	584402.19	0.47	30038.27
TAFE	B	198.99	5461.89	205810.65	0.17	10578.67
TAFE	C	504.22	13839.78	521499.42	0.42	26805.07
TAFE	D	3323.10	91212.31	3436989.15	2.79	176661.24
TAFE	E	895.98	24592.94	926691.50	0.75	47631.94
TAFE	F2	829.10	22757.16	857516.98	0.70	44076.37
TAFE	G	1513.94	41554.47	1565822.29	1.27	80483.27
TAFE	H	746.10	20478.93	771670.79	0.63	39663.88
TAFE	I	106.45	2921.84	110098.32	0.09	5659.05

Stakeholder	Building	Electrical Grid (kWh)	Gas (m3)	Gas (MJ)	t CO_2e per annum	
					Electricity	Gas
TAFE	J	181.18	4973.11	187392.64	0.15	9631.98
TAFE	K	485.17	13316.93	501797.79	0.41	25792.41
TAFE	L	351.22	9640.26	363256.43	0.30	18671.38
TAFE	M	1153.45	31659.85	1192981.24	0.97	61319.24
TAFE	N1	892.34	24493.04	922927.06	0.75	47438.45
TAFE	O	380.59	10446.54	393638.14	0.32	20233.00
TAFE	P	1424.61	39102.74	1473438.16	1.20	75734.72
TAFE	Q	818.48	22465.70	846534.47	0.69	43511.87
TAFE	W	2998.03	82289.93	3100783.43	2.52	159380.27
TAFE	Z	197.00	5407.19	203749.34	0.17	10472.72

Table 34 TAFE Water Use, 2015

Stakeholder	Building	Potable Water Used (ML)	Recycled Water Used (ML)
TAFE	A	2.24	0.00
TAFE	B	0.84	0.00
TAFE	C	0.62	0.00
TAFE	D	5.06	0.00
TAFE	E	9.80	0.00
TAFE	F2	5.85	0.00
TAFE	G	6.73	0.00
TAFE	H	7.60	0.00
TAFE	I	0.61	0.00
TAFE	J	0.00	0.00
TAFE	K	1.47	0.00
TAFE	L	1.26	0.00
TAFE	M	2.81	0.00
TAFE	N1	7.34	0.00
TAFE	O	0.00	0.00
TAFE	P	0.00	0.00
TAFE	Q	2.29	0.00
TAFE	W	17.68	0.00
TAFE	Z	2.91	0.00

Data collected for annual water use included a full breakdown of use throughout each of its buildings. Energy use and cost was however provided in total campus energy consumed. To breakdown this overall energy use, the buildings GFA was used to proportionately estimate electricity and gas use and cost per building.

5.3.4.2 TAFE Assets

TAFE provided a comprehensive asset list including details of makes, models, locations, refrigerant types and condition report comments. No predicted maintenance or replacement year was nominated, however a traffic light system was provided rating assets on condition, risk, importance and functionality. This has not been provided due to the vague nature of results.

5.3.5 Central Park

The Central Park development is a private development with significant residential and corporate interests at play. This significantly limited the ability to access energy and water consumption and the assets information sought. The project team was made aware early on that there was significant confidentiality requirements around much of the data and as there were active negotiations occurring at the time the project team were unable to access this information.

5.3.5.1 Central Park GFA, Water and Energy

Only GFA data was able to be sourced from Central Park.

5.3.5.2 Central Park Assets

No asset data was able to be sourced from Central Park.

5.3.6 Data Omissions

The following requested data was not available during Phase 1 survey and has not been accounted for in this report:

Table 35 Key Data gaps

Data Type	Stakeholders
Occupancy/Usage	UTS, TAFE, Central Park
Energy Management System or equivalent (submetering data) including energy produced onsite	TAFE, Central Park
Gas Bills	Central Park
Electricity Bills	Central Park
Asset database including maintenance and replacement schedules	Central Park

5.3.7 Future Data Use Recommendations

5.3.7.1 Procurement and LCA

Gathering procurement data allows decision makers to strategically plan for purchases and contractual agreements both internally and externally with other stakeholders. By demonstrating correlations in asset type, age, replacement year and cost, the aim is to enable stakeholders to plan bulk purchase agreements, reducing the capital expenditure required for the same item. This applies to not only physical purchases but also to resources and personnel required to maintain or replace those assets. An example might be one centralised maintenance provider maintaining all chillers in the precinct rather than employing one such provider for each stakeholder or building. The operational benefits of this, combined with the opportunity to consolidate resources within the wider precinct through shared utility use and asset use may provide an opportunity for all stakeholders involved to enhance their triple bottom line. Without careful analysis of replacement and maintenance timings, costs and other externalities, the option of a shared resource network may not necessarily be a viable one.

The data provided in the pivot table in appendix A, demonstrates a difference in the forecast asset replacement dates between UTS and TAFE. It appears that whilst TAFE has a number of units earmarked for replacement within the next 1 to 3 years (as of 2014) predominately due to the use of R22 refrigerant gas, UTS on the other hand have a steadily progressive maintenance and replacement schedule up to 2035. This perhaps demonstrates it would be unlikely for bulk purchase agreements between the two stakeholders for the procurement of new units. The pivot table displays a large replacement cost forecast by UTS of over $30m up to 2035. With such significant expenditure, it can be assumed that potential savings could also be substantial with a bulk purchase or shared user agreement.

Aside from the above, individual asset energy demand and utilisation can be investigated to further justify decision making in the procurement, decommissioning and future operation of assets. By identifying those assets at maximum load or with a forecast maximum load, we are able to exclude these in future discussions on which assets and utilities to share and not share. Location of assets to be shared against potential areas for resource consumption will be fundamental to estimate impacts (including cost) of utility connections. The impacts associated with connection, operation and procurement need to be considered holistically in decision making for any sustainable outcome to be achieved.

5.3.7.2 Energy and Water

Statistics around the future energy and water usage and associated emissions and costs will ultimately drive decision making in migrating away from business as usual methodologies and technologies towards a low carbon future. Through understanding the energy and water demand of each building we are able to pin point the major and minor consumers across each precinct or campus, comparing the geographical locations of those major consumers in relation to one another to gain a picture of where co-shared energy and water might provide the greatest benefit.

The data provided in the pivot table in appendix A, highlights the vast difference in energy and water use and associated costs between TAFE and UTS, with UTS almost consuming around 3000 times more electricity, 50 times more gas and 4.5 times more potable water than TAFE's campus per annum. This it is perhaps unsurprising given the size of the UTS Broadway campus relative to TAFE's. Looking at the locations of the three stakeholders and identifying the major energy and water producers/consumers, UTS has a number of opportunities to share thermal energy with the central thermal plant and assets in CB01, CB02 and CB03 due to their relatively close proximity to Central Park.

The data highlights minimal opportunities at present to generate and share energy through the use of on-site renewables with UTS having few renewable resources relative to demand. This is the same for recycled water usage where demand for rainwater captured outweighs supply at UTS. Understanding the resources available at Central Park including trigeneration systems, PV panels and water treatment plants, there is perhaps a greater opportunity for Central Park to share recycled/renewable resources with UTS, however without the provision of operational data for this study, the extent of this opportunity is currently unknown.

For future decision making, the data set collected in this study will need to be broadened, standardised and verified/audited for consistency across stakeholders to provide an 'apples with apples' comparison. This would include all stakeholders providing data from the same year/month/week, using the same units of measurement, calibrating meters at the same times and standardising EMS and BMS reporting. Introducing new precinct policy and governance frameworks could potentially facilitate the changes listed above. Identification of potentially sensitive intellectual property should be undertaken in early planning for future studies to mitigate gaps in the provision of information e.g. Central Park.

Utility Data Types

Billing/Account Data

Utility bill data is useful to determine the total net cost to an energy/water user. However, such data is often combined with daily service/connection charges so this needs to be taken into account when trying to determine volume based pricing for energy or water. Saving calculations also need to take into account service/connection charges which are unlikely to vary with reduced energy/water us, but may vary if fewer or additional connections are required e.g. if moving to a centralised energy/water plant to service a local precinct.

5.3.8 Assets and technology

The asset information will be focused on collecting information about the existing and proposed energy and water systems operating within the precinct within a single asset record. This asset record should enable queries to determine and test alternative asset / infrastructure solutions / management and ownership structures to enable precinct transition. Asset data will seek to identify the physical features of the precinct including:

- Building – Building Management System (BMS), Mechanical systems (including information on utility demands, asset age, replacement schedule, replacement costs, operating costs, physical location, maintenance costs, ownership, influence, issues, efficiency & efficiency potential), building hydraulics and energy distribution (hydronic etc.), Building Physics (orientation, façade typology, age)
- Precinct – Land ownership, substations and transformers, street lights, trunk utilities (water, gas, electricity) stormwater assets.
- Master plan
- Floor space survey
- Mechanical systems
- Building physics (age / typology)
- Ownership and tenancy structure
- Asset management approach
- Maintenance / replacement.

5.3.9 Utility

The utilities consumption information should be based on best available data. This would need to include base building, building tenant and public domain. The approach to standards for collection and correlation is critical across the precinct boundaries. The request for information provded to each of the key stakeholder groups included:

- Energy
  - Type – Electricity / gas. And if possible down to electrical, thermal and mechanical. Including cost where possible.
  - Scale - Consumption rate per m2 rate (based on GFA>NLA>Tennant>Use>or item to as fine a grain as possible)
  - Time of use - Consider 24 hr cycles, seasonal cycles and annual (for peak scaling and infrastructure matching)james
- Water
  - Type - potable, non potable, stormwater and waste) - Including cost where possible.
  - Scale - Consumption rate per m2 rate (based on GFA>NLA>Tennant>Use>or item to as fine a grain as possible)
  - Time – time of use if possible (for peak scaling and infrastructure matching)

• Time – time of use if possible (for peak scaling and infrastructure matching)

In terms of the data layout the utilities and asset summary was collected within the following structure:

			Area (m2)			Energy Use					Profile (%)					t CO_2e		Water Use			
Stakeholder	Building	Location	GFA	NLA	ULA	Electrical Grid (kWh)	Gas (MJ)	Renewable (kWh)	Cogeneration/Trigeneration Gas (MJ)	Cogeneration/Trigeneration Elec. Output	Heating	Cooling	Hot water use	Lighting	Other Elec. Loads	Electrcity	Gas	Potable Water Used (KL)	Recycled Water Used (KL)	Recycled Water Source	Average Utilisation (%)

Asset summary

			Asset						Installation / Replacement		Replacement/Maintenance Costs		Usage		Refridgerents		
Stakeholder	Building	Location	Asset Code	Name	Make	Model	Asset Utilisation (%)	Service Range	Installation date	Replacement date	Maintenance Costs	Replacement Cost	Nominal Energy Capacity (kW)	Nominal Water Capacity (KL)	Nomial Refridgerent Charge	Refridgerent Gas	Comments
			AIR CON	Chiller 1													

5.3.10 Precinct information model (PIM)

This report has canvassed a wide range of technologies, collaborative business models, incentive mechanisms and drivers that are able to support the management of energy and water usage at a precinct scale to reduce carbon impact. At the heart of all these mechanisms is access to data, information and knowledge in a timely fashion that can inform strategies throughout the life cycle management of a precinct. This includes planning for the installation of new technologies and built infrastructure, as well as the efficient operation of existing plant and the assessment of future space usage within the precinct.

Information modelling technologies have a proven record in facilitating the planning, design and on-going management of built facilities, implemented in a technology commonly referred to as BIM (building information modelling). The CRC-funded project RP2011, entitled Precinct Information Modelling, aims to apply these principles at the scale of a precinct to develop an open data exchange framework based on an existing international standard known as IFC. This concept has been explained fully in the CRC Scoping Study, Performance Assessment of Urban Precinct Design (Newton, et al 2013).

Within the context of the Empowering Broadway Project, the PIM will provide an open data repository that is able to accommodate the information requirements of the transition strategies that are developed for that precinct. Importantly, it places the data needs described in the previous sections within a spatial context, making the knowledge far more accessible for stakeholders.

Figure 23 illustrates the precinct modelling framework that is being developed and how it will support the Empowering Broadway project. The data schema and the data dictionary that are used to define the structure of the model are shown on the left. The precinct model itself has links to various external data sources, both directly through links from object instances in the model to operational data (where appropriate) or geo-located data (accessed using spatial queries), and indirectly to data linked via object types held in the precinct objects library. Applications can then access the information held within the PIM to carry out precinct analyses or management processes that may be required.

The PIM schema (or data model) is a proposed extension to an international standard for representing built facilities (buildingSMART International, 2015), providing a standardised format for holding precinct information in an object database, as well as a file format for the exchange of data between software applications. It is complemented by an on-line Data Dictionary (buildingSMART International, 2014), also based on an international open standard (ISO 12006-3:2007), that holds concept definitions for precinct objects and their associated properties. For the purpose of precinct-scale modelling, we identify three categories of precinct objects:

- Zones – used to represent any spatial area that has common characteristics, for example, an area within a precinct reserved for a specific type of land use, or a precinct zone that is owned / operated by a particular stakeholder.
- Features – used to represent any facility within a precinct that has relevant data associated with it, for example, a building (or other constructed facility such as a road or area of open space) treated as a single entity, or a piece of plant that delivers / consumes energy or water resources.
- Components – used to represent fine scale components that make up the fabric of the built environment, for example, building elements such as walls, windows, slabs, etc. or external infrastructure components such as kerbs, railings, pipework and services elements.

Figure 21 Precinct Information Model for Empowering Broadway

The Broadway precinct is a specific instance model based on the proposed PIM schema. As a result of its structure, including the link to a precinct object library to support the needs of the Empowering Broadway project, it is able to facilitate access to different types of external data as illustrated in Figure 23. It can be thought of as a collection of objects belonging to the three categories identified above, but structured around a spatial hierarchy that organises the information within a spatial context, for example, a building belongs to a site and is made up of storeys and spaces. Though precinct models typically include 3D geometry, that geometry is essentially only a property of the objects. A PIM can exist without any geometric data.

A core functionality of a PIM that is key to its application to the Empowering Broadway project, is its ability to support interoperability between analysis software tools. Conceptually, the entire PIM is capable of holding any information that is associated with a precinct, but whenever that information repository is accessed, only a subset of the total data is required to support a specific use case. A typical use case may be the need to perform some analysis of the precinct using a third-party software application such as SSIM, PrecinX or MUtopia. In that use case, a model view definition (MVD) can be set up that identifies only the specific data required to support that analysis using the precise software application. Similarly, a precinct information management system that supports collaborative decision-making with respect to the use of energy and water within the precinct would also rely on a subset of the entire PIM, either representing only a sub-precinct within the overall model or only specific types of object and selected properties of those. Use cases such as these can be handled by creating the appropriate filtered view of the entire model in the form of an MVD that is then applied in order to extract just the information needed to support that use case.

In order to support the information management needs of the Empowering Broadway project, the PIM team are developing prototype software tools with the following functionality:

- The ability to connect to the data repository; enter/export data; demonstrate functionality/efficacy of open schema
- A PIM Viewer (and perhaps a WEB browser interface) that connects remotely to the PIM database and supports:
  - Viewing model data as a 3D representation
  - Basic data editing capabilities, but excluding the ability to create new geometry (since that would be done using existing BIM applications)
  - Establishing and maintaining links to both an on-line data dictionary (to interrogate concept definitions and property templates) and to a prototype PIM object Library
  - Export data based on defined MVDs for import to other analysis applications
- Demonstration add-ons to current BIM authoring applications (Revit and ArchiCAD) that show how PIM objects can be created, with properties defined using the data dictionary, and linked to a PIM library.

Base PIM for Broadway

As a starting point, a base PIM has been created for the Broadway precinct based on the City of Sydney's Floor Space and Employment Survey (FSES) data (last surveyed in 2013). This is essentially an occupancy database that identifies every space within the local government area and records its geometric footprint and both ownership and usage data. Based on that information, we created a base PIM that represents those spaces as extruded polygons, arranged in buildings (associated with a cadastral entity) and storeys. Slab objects separate each floor of each building (including the roof) and generic external walls form the enclosure for each storey. That model is illustrated in Figure 22.

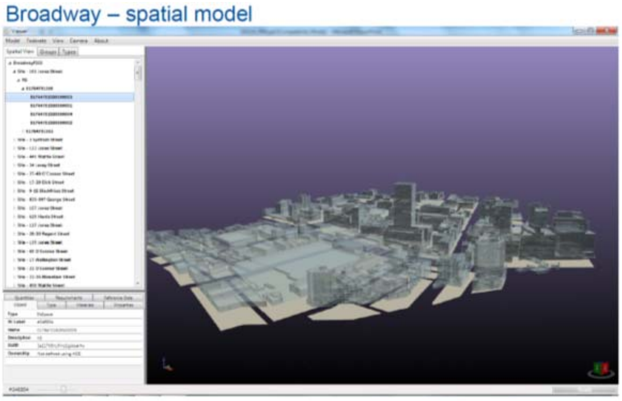


Figure 22 Broadway PIM based on the City of Sydney FSES data.

Not all the buildings within the precinct are represented in this model, particularly those constructed in recent years including all the new buildings within the Central Park development. However, where BIM models are available for any building within the precinct, then those can be merged into the PIM. For example, we have a BIM for one building within the TAFE complex that was modelled as a student exercise and we recently received the as-built BIM for the Science Building that fronts Parramatta Road.

As asset data is made available, it can be incorporated into the model and associated with the defined spaces. Similarly, ownership or operational responsibility over zones within the precinct can also be incorporated into the PIM to support the collaborative decision-making required by the transition process.

We envision taking a specific area within the overall precinct and modelling infrastructure elements such as roadways, footpaths, open space, landscape features and utility service networks to demonstrate how that level of detail can be managed within the PIM, but that will be driven by the specific data needs that are defined for the Empowering Broadway project.

A final aspect of a precinct that can be incorporated into a PIM, and may prove useful in the context of the Empowering Broadway project, is stakeholder information. This would include actor information (to define stakeholder roles), including organisation structure (responsibilities and reporting lines) and areas of responsibility (physical zones within the precinct). This would allow associating specific operational responsibilities with individual objects (plant, spaces, buildings, etc.) within the precinct, were that identified as a need with the project.

In summary, the PIM will include support for:

- Holding the base case and real-time performance data as outlined in section 9.2 and 9.3
- Providing interoperability support for analysis of the data using existing and future software tools such as SSIM and MUtopia
- Provide the ability to link to external data sources, including a Precinct Object Library with associated carbon metrics property data and real-time data feeds where available
- Providing support for scenario testing and analyses as required by the project

Anticipated Benefits of the PIM for the Empowering Broadway Project

- Repository for base line data as it becomes available
- Stakeholder interface for information entry and access, including login security protocols
- Scenario support for multiple model versions
- Support for spatial analysis of water & energy networks to assess operational and implementation costing
- Modelling of assets as a whole (aggregations) with a spatial dimension versus systems within an asset
- Piloting of data quality issues to test variance and sensitivity analysis
- Case study for data collection challenges stemming from low availability and generally poor quality of data particularly for running systems
- Testing harmonisation/adaption strategies of different metrics adopted by owners for similar performance measures
- Detailed partial model for a small portion of the site adjacent UTS Alumni Green and adjacent TAFE facilities trialling buildings, utility networks, road system and urban spaces
- Support for data interoperability / end user application

References (for this section)

Newton, P., D Marchant, J Mitchell, J Plume, S Seo & R Roggema (2013) Performance Assessment of Urban Precinct Design: A Scoping Study, CRC for Low Carbon Living, Sydney, 2013.

buildingSMART International (2015), IFC4 Add1 Release, available: http://www.buildingsmart-tech.org/specifications/ifc-releases/ifc4-add1-release

buildingSMART International (2014), Data Dictionary, available: http://buildingsmart.org/standards/standards-library-tools-services/data-dictionary/

6.0 Conclusions and Recommendations

The Phase 1 research identified a number of features of governance, business models, technologies and global case studies that may be applicable to precinct transitions. The consideration of application within Broadway Precinct was however considered closely and the ability to get a clear picture of the technical, governance, stakeholder, assets and utilities data was significantly challenged by both confidentiality and perceived value gaps in seeking to extend beyond the existing precinct.

UTS is currently expanding, operating and optimising its distributed precinct based solutions to enable greater levels of economic and carbon efficiency from its operations. This is continuing to evolve and is providing a valuable network. Tafe is operating its assets in a more independent manner but is exploring better ways to optimise their precinct systems within their facilities management teams. Both UTS and TAFE are fully occupied in enabling and optimising their own precincts. It is perceived by the research team that the additional challenge of bringing a third party into their utilities and asset model for the purposes of carbon reduction seems extra to their current challenges. Put simply, they need to sort their own systems out before they extend to optimising others.

One Central Park is already operating a commercially run precinct utility for energy and water to a wide range of stakeholders. This precinct utility has been designed to optimise the facility for the current owners / tenants and the consideration of its context within the wider precinct is limited. The project is also subject to significant confidentially and commercial terms around its operation which limit the ability enable transparency of information within the precinct.

Findings and conclusions

The findings from Phase 1 identified some of the opportunities for precinct transitions globally both in technology, governance and business cases and also identified some of the key opportunities and barriers to successful precinct based transitions for the Broadway Precinct. The research also enabled a good understanding of key information required to enable successful precinct based utility infrastructure transitions. It also provided an understanding of governance and commercial structures that may enable a successful precinct based utility infrastructure transitions

It was recognised that to reduce carbon impact, the successful implementation is significantly influenced by the precinct stakeholders, context and governance mechanisms. The stakeholders in their particular context generate the project need or define the problem. Technology is typically used to solve the problem but has to be implemented within a governance framework that will optimise its performance in terms of cost, sustainability, resilience and low carbon outcomes. It was also considered that in the context of Broadway Precinct that the stakeholders, governance frameworks are not conducive to enabling an effective precinct transition within their current form.

6.1 Recommendations for next phase research

The base research in Phase 1 has identified a number of challenging ongoing research needs and identified a preliminary data set for an existing precinct. To enable and leverage this first stage research we believe the CRC LCL could identify at least 3 2-3 Research Masters who are interested in being involved with the next stage of research. The challenges being focused in this research are mostly around the governance, business case, behavioral and economic areas and therefore the PHD / Research Masters may stem from CRC LCL partner universities from schools covering:

- Business / economics / commerce
- Sociology / philosophy / psychology
- Environmental economics
- Systems integration / Project delivery

It would be proposed that the researchers would be working alongside industry partners from AECOM, Brookfield, Urban Growth, City of Sydney, Tafe NSW and academic leaders from UNSW and Swinburn University.

Primary research questions for the next phase include:

- Identifying an optimal existing precinct for a low carbon transition to be applied. It is considered that perhaps a precinct with some individual buildings that have already been optimised in their own right, have engaged owners / tenants and facilities managers and that are ready to consider the next stage of a precinct system.
- Undertaking the literature or a meta-data study of low carbon precinct initiatives and standards to support the new National Carbon Offset Standard (NCOS) committee tasked recently with extending the existing standard to include buildings, precincts and cities.
- A focus on "Next Generation Business Models" for Distributed Energy and Water Services identifying detailed options for new business models (applicable to precinct retrofits) for eco-efficient delivery of energy and water services to enable precinct retrofitting to enable incremental demand and supply improvements.
- How will district utilities work in the face of increasing efficiencies unless the efficiencies are built in up-front in the demand planning? If the demand reduces over time (ideally) and the business case for the infrastructure stumbles then the economics around the community precinct utility could potentially falls over. Unless to the price can be floated against the infrastructure utility return however this means you end up paying more for the service if you drive up efficiency.
- The following outlines some of the secondary questions or current challenges identified through Phase 1 research which could also benefit from further in-depth research:
- User risk and reliance on precinct scale solutions is a significant challenge. For example, if the precinct is 80% reliant on a heat source from the Building X thermal plant and the owners of Building X decide to sell up the property and move on… what are you left with… Or from another perspective what if Building Y identifies a cheaper heat source and dumps the Building X heat load? What is the potential cost of this risk? How does the system manage change? What would the minimum and maximum controls need be to enable effective risk management?
- In order to enable a sustainable outcome, life cycle costs will need to be less (or risk significantly less) than the traditional supply method. This means infrastructure optimisation using the optimum economies of scale on the demand and supply side need to be considered. As does the stakeholder, financial and environmental risk profile of that optimised infrastructure. And a clear forecast for lifecycle costs (taking account of uncertain future pricing / technology) would need to be undertaken. A process needs to be developed around Net Present Value (NPV) and Cost Benefit Analysis that can effectively allocate risk and uncertainty and triple bottom line considerations.
- Developing a logical framework to demonstrate relative merits of precinct scale solutions that consider the available precinct scale data inputs and solutions available to assist decision makers and transition partners in identifying the most appropriate and efficient decision pathway. Identifying appropriate precinct scale data (standards and collection methods) and analysis processes to enable effective decision making will be required.

- Where there is existing infrastructure in place within either the buildings or precinct, what is the incentive to duplicate or replace these potentially fully functional systems outside of a typical asset life cycle? What systems would be required to enable this transition to be optimised?
- How does the economic theory called “the tragedy of the commons” relate to the principle of distributed / shared energy utilities?
- How does the emergence of the shared economy impact on precinct energy and water systems?
- Can a future planning platform be developed to enable transition teams to collaborate and test scenarios in a highly transparent format (connected to the PIM)? Connected with a precinct scale asset/utilities management system? Integrated with existing asset management standards.

Appendix

Appendix 1 – Precinct Data Sets

NOTE Full data sets witheld from public release as commercial in confidence. Speak to the researchers if required and this can be discussed with the data owners.

Appendix 2 – Workshop summary

First workshop outcomes

A preliminary workshop was held with some of the potential project partners to identify the focus on the current challenges and ideal future scenario for precinct planning. This helped us define the project / research priorities. The following table identifies the priority areas in relation to current and desired future scenarios.

	Current challenges	Ideal future scenario
	Some of the current challenges faced by the stakeholders in the room around retrofitting precincts included:	The discussion around an ideal future scenario of the environment we would like to see when planning for infrastructure retrofits in 2035 included.
High priorities	• Financing – shared infrastructure/ term of investing/ Risk • Establishing stakeholder Value • Business Case – liveability/sustainability values/ coordinated buss case/ whole of life	• A clear appreciation of the cost of carbon • A recognition of the importance of energy and water security (Resilient networks) • The ability to "Plug in & Play" – Easy to connect to (Networks and Buildings)
Lower priorities	• Building existing interface/ enabled • How to scale it • Defining the boundaries • Regulation – barriers and uncertainty • Speed of technology change • Commodity prices – variability • Managing costs/complexity of micro grid network • Technical standards defining the gauge • Value proposition/ business case • Security around access • Political leadership • Pricing of existing utilities • Climate • Construction costs • Managing complexity • Effective staging	• Foundation precinct participants & need • Stakeholder needs well understood • Customer certainty provided • Clear mandate to operate at a precinct scale • The benefits from the efficiency effectively shared across stakeholders • Regulatory support (incentives & must connect) • Skilled industry • Transparency in operation • A clear market position • Replicable • No need for policy drivers • Building owner outsourcing green kits • Simplifying the complex • A clarity in life cycle costs and where the cost lies • Effective decision making support tools that communicate effectively with stakeholders (considering cost and environmental responsibility)

Second workshop outcomes

Activity 1 - POTENTIAL INITIATIVES

Baseline

1) Mapping decentralised energy and water potential

- resources (what are we using space for)
- auditing technologies
- Linking Precinct with new builds
- Eveleigh and Bays Precinct/Darling Harbour
- Think broader than red line (on map)
- Seeding opportunities for existing communities
- Community Owned PV
- Ways businesses/homes buy-in
- Energy Efficiency Upgrades
- Precinct/UTS fund the initiatives to meet its targets
- instead of o/s offset scheme verified scheme potentially have matching funding from building owners.

2) Land Use Opportunities – TFNSW

- use of Aerial House
- apartments
- gardens
- PV
- Opportunity due to value of land
- UTS/ABC do solar together
- Mapping of solar – feasibility studies
- Capturing of heat rejection water – steam infrastructure

3) Shared vision/goals – articulate what/where we are headed

- With markers along the way i.e. 'electricity self-sufficiency by xxx'
- Standardising data – setting standards and facilitate data sharing
- Facilitate sharing of data/experience/documents/reports
- Dial before you dig example – "Share before you invest"

4) Share CRC-LCL map with urban growth

- PIM working growth – data use
- Format
- Outcomes
- CRC-LCL –Smart Locale

Summary Ideas for Collaboration – (scribing during report back)

Opportunities

- Targets –
- Leadership and Champions – opportunities for execs – high profile
- Gov underwriting to mitigate risk
- Demonstrating models and understanding what failed
- Energy market change
- $ - new funding
- Models of collaboration
- New models of governance, finance – not to challenge or oppose but find ways forward
- Data – challenge! – so overwhelmed
    - Integrated
    - Not currently standardised
- Standardised management systems needed
- Sharing and willingness to share
- Technology management
- Showcase brand, set precedents
- Resources - technology

Challenges:

- Supply – Demand Matching & integration with infrastructure
- Regulatory bodies
- Lack of precedents/examples
- Investor stagnation/cultural barriers
- The market – out of our control

ACTIVITY 2 – TABLE BRAINSTORMING - DRIVERS AND ENABLERS

1)

- For UTS, student pressure
- For Jemena, greater customer engagement, new industries e.g. water recycling
- For Brookfield, new opportunities for district-schemes, value-adding, precinct scheme frees up GFA
- Availability of data/monitoring enables innovation
- Experience with some aspects (e.g. CHP) leads to confidence in next steps (tri-gen, PV) – e.g. Castle Hill RSL
- PV prices, potential battery storage prices
- [Potential for hedging]
- [New financing options] e.g.
    - green funds, green bonds eg. NAB, EUA's,
- new market in providers,
- organisational capability
- [expectations of payback periods, instability]
- [incentives programs – feasibility studies]

2)

Social	**Stakeholder**	**Political**
Attitudes vs reality Enhanced experience New focus on customer Education (of benefits, outcomes) Personal	Fear of transparency Who carries cost/risk/opportunity	
Organisational	**Financial**	**Assets**
GHG targets (UTS, ABC) Leadership and champion Risk/political change Consistency of policy Lifecycle perspective of owners (Heritage issues -) Ongoing operational/maintenance – focus in design stage	Cost! Always present Direct action Business case Treasury funding – based on operational - no explicit asset funds	Type – existing, new -heritage Scale – small (…unreadable ?) larger – opportunities Types/access to data very complex Potential of sharing data reducing risk building knowledge transparency in negotiations

Drivers

- Resilience (safe, clean to live and work)
- De-risk investment (competitiveness)
- Community expectation/now – could change)
- Cost driver (energy no longer cheap)
- Disruptive technologies (solar, LED, batteries, Tesla)
- New investment models (leasing, green bonds, etc)
- Share market appeal (reach broader markets)
- Climate change (more extreme heat days, less rainfall each year)

3)

- COST
  - Cost allocation – who pays for new infrastructure,
  - is it future proofed,
  - IRR for developer
- Stakeholder buy-in
  - market value - product differentiation
  - FSR
- Political – negotiate with local community,
- Regulation - liveability premium is risky – regulation forces/encourages market to take risk
- Liveability –
  - lifestyle, city living,
  - customer doesn't want to have to think about it – or do it.
  - Seamless
  - Green by stealth (nudge theory)
- What does the market want?
  - cheap (affordability)
  - Different market segments (how do you meet various expectation
  - Postage stamp pricing (equity) or differential pricing
  - Can the community invest in a special purpose vehicle to do more

4)

- Incentivised – demand management??
- (increase) residential
- How to "value capture"
- IMW Renewable Energy – Broadway Shopping Centre
- Educate 1 Million people on sustainability
- Smart energy monitoring –
  - dashboards,
  - sub-metering
  - real time data
- decrease in cost – smart data
- Better utilization of centralized and decentralized plant
- Urban productivity (urban growth)
  - LFAN (*check this?)* –
  - Resilient (gas shock, climate change)
  - Density
- Parking constraints – walkable –
  - attract talent –
  - digital hub (fish burners C.S.)
- Global Economic Corridor
- Climate change
- Sydney Global competitiveness

P2

- How to make it economic today?
- Data sharing
- Collaboration
  - Park/ WIFI } – less energy
    - open spaces
    - usability
- MIRVAC – work life balance
  - Telecommuting
- Electric vehicle – congestion more issue
- Walkability and public transport – cargo bike
- Contiguos spaces – urban food production
- Drought/price

SUMMARY SCRIBING FROM REPORT BACK:

- Community – existing, new – local around projects
  - Different for different stakeholders
- ***Cost/change in prices – tech
  - benefit – precinct
- Disruptive Tech
- New models – EOAs etc, green bonds.
  - financial models
  - share market appeal
- Targets
  - policies, commitments to meet,
  - organizational
- Leadership – vision
- Change – adaptability
- Perspective – LCA
- Asset cycles - cost/benefit
- Data – potential if have

  - sharing and availability – enables innovation
- Risk – who carries it
- Policy/Regulatory

P2

- Education
  - responsibility
  - ownership
- Customer - customer support and engagement
- Global competitiveness - > Sydney – attracting future generations
- Urban productivity
  - transport, design - gaps, strengths, weaknesses
  - food production
- Plant/investment Productivity
- Stakeholder pressure – students
- Competition – more providers
- Livability
  - market demand – seamless, but choice,
  - de-risking
- Market – affordability – postage stamp pricing?
  - driving investment patterns

ACTIVITY 3 – CHALLENGES AND OPPORTUNITIES FOR IMPLEMENTING LOW CARBON ENERGY/WATER PROJECTS

(note: delineation of control influence/concern is not as fixed as indicated by these tables – this is a rough approximation of where the text was located).

✪ □= 1 vote

	Challenges	Opportunities
Control	9)	UTS, TAFE ABC are owner – occupiers and Frasers/Sekisui have controlling management structures Targets, focus management ✪ ✪✪ Leadership, champions ✪✪✪ Redefine roles of utility eg. SWC facilitator vs competition ✪ Need Gov't/institutional underwriting to mitigate risk eg better cities ✪✪
Influence	How to maintain equity when providing different levels of service, qualities Rating schemes need to recognize precinct systems which can be associated with risk, business risk. Maintenance and operating costs associated with small scale systems Examples or research that suggests failure can set back especially for institutions	Added value associated with precinct systems Sharing responsibility /ownership of precinct schemes vs individual developers, individual buildings Demonstrate a model for precinct systems that can be replicated elsewhere ✪✪✪✪ Research into examples that have 'failed' to find lessons
Concern		

Symbols indicate connections made between these points.

10) Community Demand (Residents/Students), Procure business cases Market Hut – developer don't need How to engage senior stakeholders Incumbent utility engagement Incumbent utility engagement ★What data is relevant (CRC – 1year – need multi year) ★Complexity of number of people	Control		Political winds of change – state targets ★Finding a senior champion Cocktail party Tangible outcomes Awareness Commercial build sustainability expected ★Collaboration Energy Market Change
Regulation – proportionality Ability to get data* Energy market Internal changes - business models	Influence	Influence	• New management (eg UNSW) • Data tools/single format Save money
Energy market change Probity Money (TAFE) Hard to retrofit Government decision making	Concern	Concern	• New technologies – storage, solar, microgrid • New ways of funding

11) **Clients/stakeholders** Energy and water isn't core business AND still relatively low cost Lack of long-term life cycle view often reactive maintenance Overwhelmed with choice hard to get good independent advice	Control	Control	Working at precinct level can facilitate collaborative ways of working – re. distributed precinct approach ✪ New models at funding, building, govern shared infrastructure

Infrastructure wide thinking ✪Lack of or inadequate integrated data which is essential to move from old to new ways of operating Data standards	Influence	Influence	
	Concern	Concern	

12) Regulation e.g. VPN, NEL Existing contracts – limited ability to introduce innovation in contracts (procurement rules) ✪Supply/demand matching ✪Integration of old and new – never the 'right' time Information asymmetry – eg. UTS vs ABC Getting the incentives right	✪Emergence of shared resources – drive societal change ✪Advancing technology – IT, solar, batteries Increased level of advocacy from key stakeholders – eg BBP More active engagement by market players Capacity to scenario model

13) ✪✪✪ Lack of precedence/examples = risk Value asset-risk/link-asset to customer Insurance	Control	Control	To set precedence – add to brand ✪ ✪✪✪ Showcase - gov org/universities
✪✪✪ Investor stagnation – 15 yrs (GFC, “Sydney’s full”, culture barriers divided by roads, topo, fragmented) ✪✪✪ Apathy – knowledge = mojo Constrained/tall poppy Syd – infrastructure hub of world: G20 – political motivator	Influence	Influence	Funding opportunities available? (assets) find project Communicators in educators ✪✪✪✪ Export knowledge to world ✪✪✪
Opportunities to collaborate with other reputable organisation	Concern	Concern	

20) Lack of precedents/examples Investor stagnation – cultural barriers Control Market	Sharing and willingness to share Tech management Showcase – brand – set precedents Research - tech

Appendix 3 – Global Case Studies

Summary of Global Case Studies

To understand the potential pathways for the transition of the Broadway Precinct it is critical to review existing projects that had the similar objective of decarbonising the locale. While there were no direct comparisons, we adopted an approach which sought to understand key characteristics of successful transitions, and learn lessons from those that were less successful. It is hoped that the insights and lessons from this process would then inform collective planning for the retrofit of high density precincts.

The team researched global case studies where retrofit of precincts had been undertaken with low carbon technologies and management practices in mind. Significant literature and practice exists around the design of new precincts notably by the World Green Building Council and affiliate organisations, Living Building Challenge and One Planet Living, however there is a less evolved understanding of the Low Carbon transitions of the existing built environment.

Case Study Selection and Approach

A long list of international cases was identified from academic literature, government research reports, professional/industry magazines and online media resources.

A short list was developed and an in-depth desk top analysis of selected precincts was conducted where we identified valuable lessons for application to the Broadway precinct in Sydney. Verification of environmental performance and social benefits were often not possible as few claims were supported by independent auditing. In addition, much of the valuable insight was available only on company websites, which may be biased.

As such a quantitative process was inappropriate, and the themes and factors correlated with successful outcomes have been analysed more qualitatively.

The scope of the review was narrowed to developed nations and case studies analysed in more detail were biased towards innovation and change creation (including new business models) and commercialised technologies which have not been widely deployed in Sydney. Energy projects also dominated due to greater media attention although it is acknowledged that water and waste projects can have significant carbon abatement outcomes in high density environments.

Project Typologies

From the cases studied we found various types of retrofit projects including:

- **Decentralised infrastructure** including district energy, heating, cooling and recycled water schemes that replace energy or water used with a more sustainable resource (such as waste heat, renewable or low carbon energy or recycled water),
- **Demand reduction programs** that focus on efficiency retrofit and behaviour change to reduce the total amount of resource consumed,
- **Off-site resource use** – direct negotiation with external parties of power purchase agreements that can reduce carbon intensity of grid supplied electricity
- **New precincts** – that export thermal, renewable or low carbon energy or recycled water to the surrounding neighbourhood.

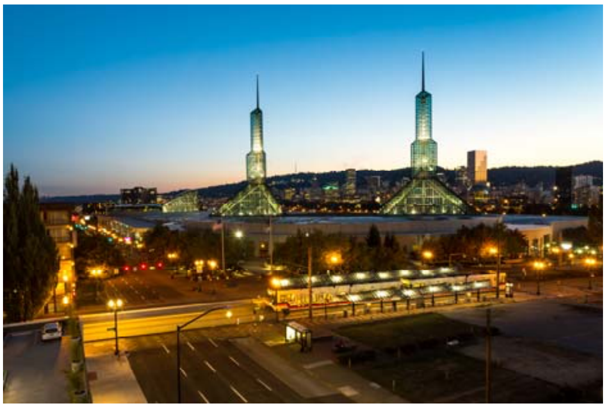
This study focuses heavily on the most relevant cases: decentralised infrastructure and demand reduction programs. Some examples of new precinct extensions and off-site renewables, which are becoming popular in the United States, are also provided. Because of a shortage of cases that deal strictly with the precinct, building or city scale, cases have been included where relevant lessons exist for precincts.

North-East America's Lloyd EcoDistrict Case Study

Location	United States, East of Portland's central business district
Site Area (ha)	162 [1] or 121 [3]
Floor space (m^2)	1.1 million existing, increasing to 3.1 million in 25 years [1]
Capacity	16,000 employees, 400 residents [3]
Usage Mix*	5 ; 61 ; 16 [3] : residential/commercial/institutional
Website	*www.ecolloyd.org*

Lloyd EcoDistrict is part of an urban renewal area, currently dominated by commercial uses and relatively new buildings. The precinct contains a shopping mall, several major event spaces, high- and low-rise commercial office buildings, surface parking and open parkland. 4

Lloyd was one of the original test sites for the EcoDistricts Protocol – a collaborative process to bring district stakeholders together to find collective solutions to social, economic and environmental problems at the precinct scale.



Lloyd EcoDistrict Stakeholders

Stakeholders are predominantly local government and district businesses, with the community (not-for-profit sector) and energy utilities also represented. Property owners and managers appear to be driven by a combination of concern for the environment and social issues, a desire to differentiate themselves from competitors via environmental and/or social responsibility and a desire to reduce building operating costs. Resilience to major storms and high resource (energy and water) prices are not mentioned as major drivers to the Lloyd EcoDistricts formation process.

Building Owners/ Property Managers/ Developers	Ashforth Pacific, The Left Bank, Oregon Convention Centre, and others[4]
Utility	Bonneville Power Administration, PacificCorp[4]
State Government	Oregon Solutions [1,4]
Local Government	City of Portland Bureau of Environmental Services (BES) and Bureau of Planning and Sustainability (BPS), Portland Development Commission (PDC), Metro and PoSI.[3]
Private Companies	Identified as needed to deliver infrastructure projects such as solar and district energy schemes. [2] Service providers not generally involved in governance structures.
Community	Portland Trail Blazers – Basketball Team

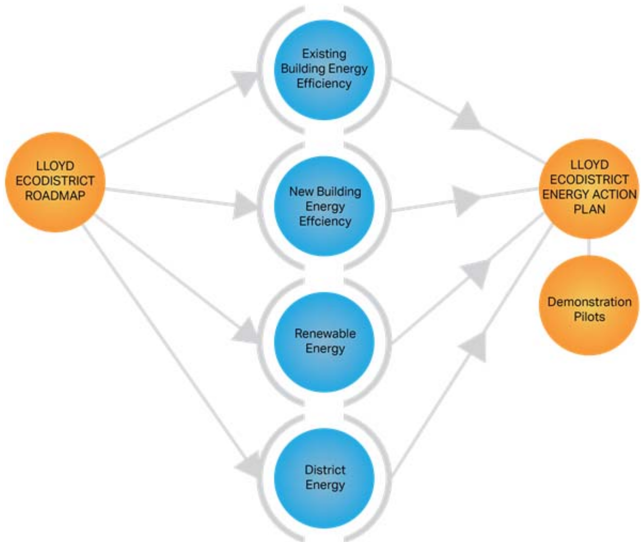


Figure 23

Lloyd EcoDistrict Governance

The creation of a collaborative governance structure in the Lloyd EcoDistrict, was an exemplar process to advance collective action at the precinct level

(Ecodistricts, 2015). Facilitated by Oregon Solutions, (a state government office) the Lloyd EcoDistricts Task Force, set goals and objectives, prioritised possible district scale projects and created a set of precinct baseline metrics. The process ended with the creation of a Declaration of Cooperation (DOC), including financial and in-kind commitments from many of the private and public sector partners of the Lloyd EcoDistrict task force.

Today the Lloyd EcoDistrict governance structure is made up of a Stakeholder Advisory Committee (SAC) to make decisions on behalf of the precinct and a Project Management Team to implement projects agreed to by the SAC. The SAC is mainly comprised of district land owners and building managers, local government departments and utilities, whereas the PMT is made up of project managers, service providers (primarily consultants) and technical experts from government (Lloyd Ecodistrict, 2014). Guidance throughout is provided by the EcoDistricts parent organisation which is funded by Portland City (Portland Sustainability Institute, 2012).

The Lloyd EcoDistrict followed a process that was later articulated in the EcoDistricts Protocol. After the governance structure was formalised, stakeholders co-created the Lloyd EcoDistricts Roadmap that set the vision for the precinct to be the most sustainable business district in North America (Portland Sustainability Institute, 2012). Goals and targets across seven performance areas were set including return on investment, job growth, water, energy, materials management, habitat and ecosystems, and access and mobility. Targets for operational energy and water usage stated in the roadmap include a reduction of 60% and 58% consecutively over 20 year for existing buildings. Baseline performance was measured across key performance metrics. A high level feasibility assessment of projects to meet stated targets was conducted as well as partnerships and strategies to finance different project types. Major funding strategies pursued include:

- Resource consumption charges collected via utility bills,
- Access to public infrastructure funds for local infrastructure projects,
- Proportion of parking fine or developer fee revenues collected by the City of Portland,
- District “tax” to fund EcoDistricts personnel.
- Lloyd EcoDistrict Technical Solutions

An overview of projects considered is presented in the roadmap, with more detail provided in the 5 year Lloyd EcoDistrict Energy Action Plan. Energy projects, divided across delivery partners are summarised in table ?. Less has been articulated about water saving projects, however it is likely to involve similar project typologies: i.e. new building performance standards, building retrofit and district infrastructure supported by catalyser programs.

Table 36

Project Type	Building Efficiency	Infrastructure	Management/Catalyzers
Projects	Individual Building Retrofits New Building Energy Use Intensity Standards Bulk Purchase Demonstration Pilot (Solar)	Roof-top solar District Energy	Energy Efficiency Working Group Existing Building Energy Protocol Energy Monitoring and Benchmarking
Delivery	Building Owners	3rd Party Service Provider	EcoDistricts

Technical solutions selected are mainstream commercially viable technologies, including roof top photovoltaics, building lighting retrofit and plant efficiency upgrades and cogeneration district energy schemes. Some consideration was however given to expansion into non-commercially available technologies in the future. For example, the Rose Quarter District Energy System Feasibility Study considered gas boilers with waste heat recovery, biomass boilers and gas/biogas cogeneration. Future anaerobic digestion of food waste was also considered at later stages. However, after a more detailed analysis, British

Columbia-based firm, Corix concluded that a shared thermal energy system would be technically feasible but the cost-benefit analysis projected lower returns then required by a private utility to secure investment in the project (Ecodistricts, 2015).

Technical synergies between projects were identifies to take advantage of potential cost savings. For example, synergies between potential district heating pipework installation and Halliday Green Street upgrade were identified as was the potential to extend the system to the shopping centre (Lloyd Centre Mall). Examples of synergies in data collection were also evident. For example, the building energy efficiency program assisted EcoDistricts to collect baseline energy usage data and critical information about existing building assets that could allow district energy schemes to be more viable. Ground work could also be done to identify what organisational preparations would be necessary to integrate a district scale scheme.

Lloyd EcoDistrict Benefits

The benefits of the EcoDistricts approach are summarised for each stakeholder in the table below. Although the EcoDistricts building energy programs and collective purchasing agreements are well advanced; district energy infrastructure continues to be allusive. Green street, stormwater and bike track infrastructure upgrades have however been successful in several Portland EcoDistricts including Lloyd. The overall district progress towards stated targets is not yet publically available, although EcoDistricts has produced a prolific literature on transition processes, projects, barriers and enablers.

Table 37

Stakeholder	Advantages
Precinct Landowner	• Drive down building operating, maintenance and utility costs [2] • District scale planning attracts investment • Green/innovation branding, tenant satisfaction, customer loyalty • Place making and increasing real estate value • Get ahead of the policy change • Identification of project synergies to lower capital costs
Service Providers	• A district strategy gives market certainty for public and private investors • Identification of project synergies to lower capital costs
Government	• Higher penetration and uptake of existing council programs • Implementation of Local Government Plans and social objectives such as job creation and place making • Improved land value leads to higher revenue generation via property taxes • Identification of project synergies to lower capital costs

Lloyd EcoDistrict Context

Contextual factors in Portland have significantly contributed to the success of EcoDistricts in implementing change. Portland City Council is supportive of sustainability initiatives and originally funded the Portland Sustainability Institute (Portland Sustainability Institute, 2012). All EcoDistricts are urban renewal projects and have access to funds via the Portland Development Commission. This contribution is substantial and it is not yet clear if the model would work as well for projects that do not attract this level of funding (Overdevest, 2011). Evidence exists of a history and culture of collective governance structures in Portland between government and civic partners. In 1994 the Transportation Management Association, a partnership between the City of Portland and public transportation agency, TriMet, was founded to effect significant change in commuter mode choices (Portland Sustainability Institute, 2011d). Much of the success of the Lloyd EcoDistricts has been attributed to the previous work of the Lloyd TMA, “proving that building off of an existing organizational structure, relationships, trust, and capacity can lead to advanced outcomes when compared to establishing a new organization” (Pilot Program Report). The existence of the local business improvement district was critical with regard to legality and funding of EcoDistrict projects. Business Improvement District (BID) was established in 2001, which aimed to facilitate transportation, public safety and economic development programs for the district (Berry, 2010). Originally the Lloyd EcoDistricts was a sub-committee of a Business Improvement District (Portland Sustainability Institute, 2011d) and a business tax collected by the BID funded the first full time EcoDistricts coordinator (Overdevest 2011).

North America’s 2030 District Case Study

Location	**United States, in Seattle’s Commercial Business District**
Floor space (m^2)	4.2 million in 2015
Members	Over 100 members with 133 buildings in 2013
Capacity	
Usage Mix*	Predominantly commercial and institutional

2030 Districts was created by Architecture 2030, a not-for-profit organisation committed to reducing greenhouse gas emissions from existing buildings in the high density environment (2030 Districts, 2013a). 2030 Districts focuses on the uptake of best practice carbon reduction measures in commercial buildings in North America. By becoming a 2030 District member, building property managers and owners, commit to reducing existing building operational energy and water usage and carbon emissions from transport by 50% by 2030.

2030 District Stakeholders

2030 districts stresses the importance of being private sector led to remain “in touch with market realities” (2030 Districts, 2013a). Actors include:

- property owners, developers and managers,
- service providers such as consultants,
- professional organisations like BOMA (Building Operators and Managers Association),
- not-for-profit organisations, and
- government.

Members are made aware of benefits and commitments from 2030 Districts membership and hence share common expectations (one of the key success factors from Strategic Niche Management). These expectations are articulated in the membership documentation and summarised Table 39 below. Property owners and managers are motivated by similar drivers; to act on climate change, to save money through more efficient operation and to gain a positive “green” image and hence differentiate themselves from competitors.

Table 38 Benefits and Commitments of 2030District Members (2030 Districts, 2015c)

Membership Group	Benefit	Commitment
Building owners and managers	Building audit, anonymous benchmarking, and retrofit strategy service In-kind services (especially around feasibility analysis) Special deals and discounts. e.g. workplace travel audit, discount EV charging stations, discount energy monitoring software Training and networking Policy influence	Share building energy water and transport data with the 2030 Staff Provide case studies and lessons learnt Participate in LEED performance if LEED certified Support committee and attend district meetings
Not for profits - community organisations, research organisations and industry associations	Access to members Furthering their core objectives	Share expertise especially for training and knowledge transfer
Service Providers	Knowledge of district project progress Access to members for advertising purposes Approved list of contractors	Offer discounted products and services, free opinion /advice etc. Attend 3 “task force” meetings per year

2030 District Governance

The district formation process is composed of three phases (2030 Districts, 2015a). The phases relate to the gradual formation of relationships that contribute to a district governance structure (2030 Districts, 2015b); from a verbal commitment among a few key stakeholders to a written commitment to the 2030 Challenge targets and formation of an official transparent district governance structure (2030 Districts, 2015a). Because goals are pre-set, there is no collective visioning process undertaken by 2030 District members.

The Seattle 2030 Districts Board of Directors is comprised of 6 community members 9 property owners and 6 professional stakeholders, reflecting the focus on the private sector. Originally volunteer based in 2010, Seattle 2030 Districts has secured grant funding and donations to continue operations (Seattle 2030 District, 2013). Although membership is free, fees may have to be charged in the future (2030 Districts, 2013b).

Although members embark on an individual organisational journey of transformation, it is hoped that the relationships formed by actor networks will facilitate collective investment in district projects and infrastructure (2030 Districts, 2015c) although little evidence of infrastructure planning is publically available to date.

After forming Seattle 2030 Districts in 2010, 2030 Districts won considerable grant monies from the US EPA to undertake projects including a $2 million USD grant to formulate the 2030District program and a tool kit for small commercial buildings, another key output. The 2030 Districts model itself will also be applied to different contexts, in nine other North American cities in an attempt to broaden impact.

2030 District Technical Solutions

Technical solutions include commercially available retrofit options such as LED lighting and building energy management software. The emphasis is on the delivery of services and training to guide all operators through the change process. Members also have involvement in more innovative pilot programs. For example Seattle 2030 Districts has partnered with Seattle Light (public energy utility), Microsoft and Accenture to trial cloud based building management software via the Smart Building Pilot Program. In another example, 2030 Districts, partnered with Nissan North America to offer its members the opportunity to have an electric vehicle charging station installed in building garages throughout the district for little or no cost. In exchange 2030 districts co-sponsored a series of Ride and Drive events where members were able to test drive Nissan's electric vehicle.

2030 District Benefits

The key service offered is the organisational change program, "Assess Target Deliver". Coaching is offered to guide building owners and managers through building assessment, assist with target setting and implementation of viable energy water and transport emission reduction projects (Seattle 2030 District, 2015b). Members are also given access to 2030 Districts Network tools, training and support, and connected to sustainable goods and services providers to adopt best practice management strategies in energy, water and transport within their organisation (2030 Districts, 2015a). Performance data may be shared with 2030 Districts staff and buildings are anonymously compared to similar building typologies in the district. However only aggregated data is made publically available (2030 Districts, 2015a). Seattle's performance against three categories is reported below:

- 19% reduction in energy consumption,
- 6% reduction in water use,
- 6% reduction in Transport emissions (Seattle 2030 District, 2015a).

The primary benefit of 2030 Districts is that it stimulates whole new niche market for sustainable services in the local precinct, creating a protected space for innovative service delivery. Improving knowledge flows can stimulate supply and demand for sustainable services in the precinct, improving local market efficiency by reducing transaction costs . For example, the small commercial buildings toolkit improves understanding of potential savings from energy retrofit for small commercial office and retail buildings. In addition to this, HVAC (Heating, Ventilation and Air Conditioning) contractors are trained to deliver the energy management program. Within these new markets, innovation in service delivery and project implementation may occur. In the example above HVAC contractor training seems to introduce the concept of partnering with the client to set performance targets, thereby potentially changing the relationship dynamics. By stimulating both the supply of and demand for services, a robust market-place can evolve for an extended period of time; long enough for new practices to be adopted by building managers in the precinct.

2030 District Context

Like Portland, Seattle has a history of Business Improvement Areas, which may contribute to the success of 2030 Districts via setting a precedent for business collaboration. The Metropolitan Improvement District (MID) is a non-profit organization that provides streetscape cleaning, maintenance, hospitality and public safety services, as well as destination marketing, human services outreach, research and market analysis for Downtown Seattle. Founded by the Downtown Seattle Association in 1999, the MID is financed through tax assessments on Downtown properties (Downtown Seattle, 2013).

Canadian Dockside Green Case Study

Location	**Inner Harbour, Victoria, British Columbia, Canada**
Site Area (ha)	6.1
Dockside Green	120,000, 26 buildings
Capacity	2500 residents
Usage Mix*	73% residential

Brownfield redevelopment near inner harbour in Victoria. Designed to LEED-NC and LEED-ND Platinum standards. The objective of the site was to be carbon neutral, with strong links to biodiversity through water feature incorporating storm water management. Strong links to outside community.

Dockside Green Stakeholders

Developers	**Vancity Credit Union, a member-owned financial co-operative**
	Windmill Development (a green development Company)
Government	City of Victoria
Community	Victoria West Community Association

Dockside Green Governance

The owners and developers at the time, Vancity Credit Union and Windmill Development, pledged to build LEED-Platinum buildings, agreed to pay a potential $1 million penalty if they didn't achieve this goal. The developers were successful in meeting LEED-Platinum for their first two residential phases, "Synergy" and "Balance," and the first phase of commercial development, "Inspiration".

Initially, Vancity provided funding, but later became development partners with Windmill, creating Dockside Green Ltd., and finally bought Windmill's 25% to become the sole owners creating Dockside Green PLC

The City of Victoria provided a dedicated staff member for the development process and Dockside Green Ltd. paid for part of the costs. The City also formed an interdisciplinary project team to help with the approval process to overcome the typical silos that are common to many city organizations. The inclusion of novel technologies did, however, slow the permitting process. The city allowed developers to defer payment for the land to avoid bridging financing.

During preliminary consultation, the city engaged with the adjacent neighbourhood, Victoria West Community Association, to help develop the evaluation criteria for the Request for Proposals The City embedded tough sustainability targets within . all phases of the development which was a critical success factor. The development was a very high-profile project with community support, and was featured prominently in local and green building professional news.

Dockside Green Technical Solutions

- Cogeneration Plant fuelled by wood waste gasification plant approaching carbon neutrality
- Membrane bioreactor to recycle water for toilet flushing landscape use
- Incorporation of stormwater management into landscaping features
- Had to build energy plant up front- large amount of sunk costs with no income

Green technologies are prevalent at Dockside Green and reflected in everything from the kitchen appliances to the heating and air ventilation system inside each condominium. In addition to efficient fixtures such as hardwired compact fluorescent and LED lights, units include ambitious features such as Internet-enabled controls that let residents view water, heat, and electrical consumption and even control the HVAC system. If, for example, weather conditions warm up at home, residents can turn down the heat remotely.

- Careful attention is paid to the exterior of the units as well. On the south side of the condo¬minium units automated awning blinds block the steep angle of sunlight and heat during the day in the summer, while vertical blinds on the west side block the direct sunlight. Green roofs featuring sedums, vegetable gardens and trees have been constructed, and more than 1,800 trees will be planted in the community.

- The community relies on a state-of-the-art naturalized creek system and on-site water treatment plant that will not be connected to municipal storm water and sewer systems. The creek bed is lined with plants that will naturally clean storm water, while the treatment plant treats 100 per¬cent of the sewage generated by the development and uses the treated water for flushing toilets and irrigating landscaping. This closed-loop system not only creates a natural habitat but also takes waste from one area to provide food for another.

Dockside Green Benefits

- Carbon Neutral when energy plant fully operational
- Social housing
- Biodiversity enhancement
- Land decontamination
- 30% less water use

Focus case examples

City of Sydney Decentralised Energy Plan

The City of Sydney introduced its Decentralised Energy master plan in March 2013 (Kinesis, 2013). It was an ambitious plan which would see trigeneration systems implemented across the city to provide low carbon heating, cooling and electricity. It later released a renewable energy and energy efficiency master plan which together sought to identify opportunities to deliver carbon reductions across the LGA.

The council had a number of key public policy goals, but primarily they sought to reduce the carbon intensity of the city by 26% below 2006 levels by 2030. This reduction was to be achieved in the most cost effective way per tonne of CO_2e . This goal also has overlapped with several other policy goals at a state and federal level such as reducing utility costs to consumers, achieving energy security, managing implementation of new technologies, and the ability manage long term infrastructure needs of the city (which powers economic growth).

The City of Sydney has fought to enact its Trigeneration Master Plan, proving their level of commitment to a transition to a sustainable low carbon future. However delivery of the Master Plan was complicated by the relience on the private sector to deliver infrastructure projects and significant policy and legislative changes from state government institutions to remove barriers, reduce risk and increase profitability of the schemes. City of Sydney has explored some of the possible changes by government policy makers, utilities and energy markets to transition City of Sydney to a low carbon economy. In particular, the current utility pricing arrangements includes a prohibitive cost of transporting electricity short distances from a local generator to a neighbouring site (Coombes & Jones 2013). Currently in NSW, decentralised energy is exposed to the same costs as centralised generation even though decentralised power makes little or no use of big transmission networks (Jones 2010). Legislation changes to enable electricity, hot water and even gas to be exported and sold to a local distribution network would facilitate greenhouse gas reduction.

To mobilise private sector investment and enact the master plan, Sydney established a municipally owned company led by the Lord Mayor, called the Sydney Climate Change Agency Ltd (SCCA) to implement public/private joint venture carbon abatement projects (Jones 2008). The SCCA formed an ESCO with Energy Australia to facilitate trade and supply of electricity over the public wires network at retail prices (Bunning 2010).

After a two year negotiation process, the City of Sydney has postponed the first major stage of its decentralised energy network. City of Sydney cited a combination of government and energy network red tape, as well as gas and carbon price uncertainty undermining the commercial feasibility of the project (Vorrath 2013). It is also clear that the expectation for individual building owners to install adsorption chillers was a major barrier to the process, although it offers the most technically feasible option. It is clear that the policy and institutional barriers will prove to be just as significant a challenge to the network as the technical barriers.

Despite these positive goals, in August 2012 it had become clear that there were misalignments between key stakeholders within industry and the City of Sydney's plan. In a presentation to property owners who would need to connect their buildings to the centralised systems it became clear that they felt alienated from the process.

NY community microgrid peer-to-peer rooftop solar trading

A team of engineers, software developers, energy analysts and renewables developers have joined forces to build a ground-breaking locally generated electricity microgrid in the New York borough of Brooklyn, with the goal of allowing locally connected residents to buy and sell renewable energy from neighbourhood rooftop solar installations. This was developed by a team of engineers, software developers, energy analysts and renewables developers have joined forces to build a ground-breaking locally generated electricity microgrid in the New York borough of Brooklyn, with the ultimate goal of allowing locally connected residents to buy and sell renewable energy from neighbourhood rooftop solar installations. The Brooklyn Microgrid – a joint venture between LO3 Energy and Consensus Systems – will use a platform called the TransActive Grid, which uses software and hardware to enable its members to engage in trading energy from each other, known as peer-to-peer trading. The first phase of the project will essentially connect houses with solar panels with other nearby houses that want to buy renewable energy. From that point, a desginated "distributed energy development group" – including the Park Slope and Gowanus communities of Brooklyn – will be connected by constantly updated "cryptographically secure list" that is stored on devices at each location. Software called Ethereum is used to monitor the energy in and energy out of each point of the network.

Source: http://onestepoffthegrid.com.au/ny-community-microgrid-to-allow-peer-to-peer-rooftop-solar-trading

Appendix 4 – Global Case Study Long List

This is the long and short list for the case studies.

Scheme	Location	Precinct Area	New/ Existing Buildings	High Density? People/m2	Implemented?	Refs
Review IDEA Case Studies						http://www.districtenergy.org/case-studies
Barcelona	Spain		Existing	Some		https://www.logstor.com/EN/District-Heating-and-Cooling/References/Pages/Barcelona.aspx
Toronto Enwave			Existing	Some	yes	http://www.enwave.com/history.html
Austin Texas				Some		
London				Yes		
Honolulu				Some		
Alexandria District Energy Utility,	Richmond, BC, Canada		New Green Field Development	Medium - Commercial and Res	Yes	https://www.youtube.com/watch?v=c_Ahh7VGjCo&feature=youtu.be
Dockside Green			New	Medium-High	Yes	https://www.youtube.com/v/7T8ZOEBDh2o http://www.nexterra.ca/files/dockside-green.php
Sth Korea				CES Projects small scale for high density heating and power District chilling supplied to buildings - adsorbtion chillers		
Brisbane				Yes		
River District Vancouver			New			
Revelstoke	British Columbia		Existing	No		
South Vancouver	British Columbia					
Burnaby	Canada		Existing	No		

Scheme	Location	Precinct Area	New/ Existing Buildings	High Density? People/m2	Implemented?	Refs
Vancouver Metro	Canada		Existing	Yes		
Doncaster Hill Smart Energy Zone - outer Melbourne	Australia		Existing?	No - residential	Yes	
SE False Creek Neighborhood Energy Utility:			New	Predominantly res? Maybe Medium?		vancouver.ca/home-propertydevel-opment/neighbourhood-energy-utility.aspx
Nashville District Energy System:						http://www.nashville.gov/des/his- tory_of_metro.asp
Seattle Steam District Energy System:						seattlesteam.com
Yokohama Research Institute						http://www.japanfs.org/en/news/archives/news_id029184.html
Makuhari District Heating & Cooling Center						
Stockholm						http://international.stockholm.se/International-Relations/professional-study-visits/6-district-heating-and-cooling1/
Ball State University			Existing	No		http://www.districtenergy.org/assets/pdfs/2011Campus_Miami/Wednesday/1B1LusterMURLAUBBSUGeothermalSystemsCampusScale.pdf
Co-op City Bronx	NY					
Portland Rose Quarter?						
Bunhill Heat and Power	London		Existing	Medium?	yes	
Dubai			Existing	mix	yes	
Brest	France		Existing			
Bergen	Norway?		Existing			
London Olympic park			New			

Scheme	Location	Precinct Area	New/ Existing Buildings	High Density? People/m2	Implemented?	Refs
Anshan	Denmark		Existing			
Port Luis Sea Water Air Con	Maritius		Existing	Some	no	

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1Transaction costs are a major barrier to enter a new market. They are associated with information (service availability, quality and value for money), bargaining costs (especially associated with tendering and contract formulation) and policing (or evaluating performance according to the contract).