



Final Report

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# **Resilient urban systems: a socio-technical study of community scale climate change adaptation initiatives**

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## Resilient urban systems project overview

The resilient urban systems project aims to improve understanding of motivations to develop new systems of energy and water provision, opportunities and barriers to implementation and changes in practice resulting from these new systems. This brief is one of a number of project outputs that include journal articles, progress and final reports.

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The Project Reference Group includes representatives from the Department of Planning and Community Development (DPCD), Department of Sustainability and Environment (DSE), Department of Human Services (DHS), the Alternative Technology Association (ATA), Yarra Valley Water and the Environmental Sustainability Accord (The Accord).

Visit the VCCCAR website for more information about the Urban Resilience Project:  
[www.vcccar.org.au](http://www.vcccar.org.au)

# Contents

<b>1. Key findings</b>	<b>5</b>
<b>2. Introduction</b>	<b>6</b>
2.1 Our definition of resilience	6
2.2 Emerging infrastructure supply models	8
2.3 Linking infrastructure design with adaptive capacity	9
<b>3. Aims and Approach</b>	<b>10</b>
3.1 Methods and approach	10
3.2 Collaboration and support	12
3.3 Socio-technical framework	13
<b>4. Results</b>	<b>14</b>
4.1 Innovative energy and water systems in Victoria	14
4.2 Details of case studies	14
4.2.1 Aurora	14
4.2.1.1 Overview of energy and water systems	14
4.2.2 WestWyck	16
4.2.2.1 Overview of energy and water systems	17
4.3 Living with alternative systems	19
4.3.1 Householder backgrounds and reasons for moving	19
4.3.2 Changes in practices	20
4.3.3 Perceptions of risk and resilience	23
4.4 Risk and hazard context	25
4.4.1 Perceived hazards	25
4.4.3 Projected climate hazards	28
4.4.4 Overview of potential impacts to services	29
<b>5. Analysis of system resilience and adaptive capacity</b>	<b>30</b>
5.1 Technical enablers of resilience	30
5.2 Institutional governance and management enablers	34
5.3 Social enablers	37
5.3.1 Knowledge	38
5.3.1.1 Experience	38
5.3.1.2 Diversity	39
5.3.1.3 Community cohesion and knowledge sharing	39
5.3.2 Context	41
5.3.2.1 Priorities and finances	41
5.3.2.2 House and system design	42
5.3.3 Agency	44
5.3.3.1 Community organisation and system governance	44
5.3.3.2 Co-management	46

5.4 Implications for supporting resilient infrastructure .....	47
5.4.1 Replicability .....	47
5.4.2 Managing climate uncertainty .....	48
<b>6. Research outcomes .....</b>	<b>50</b>
6.1 Enablers of resilience .....	50
6.2 Key findings .....	52
6.3 Preliminary assessment criteria .....	54
<b>7. Conclusions .....</b>	<b>55</b>
7.1 Recommendations for future research .....	56
<b>Glossary .....</b>	<b>57</b>
<b>References .....</b>	<b>58</b>

## List of figures

<b>Figure 1:</b> Spectrum of water and energy systems.....	8
<b>Figure 2:</b> Project activities and timeline.....	12
<b>Figure 3:</b> Framework for socio-technical system resilience.....	13
<b>Figure 4:</b> Aurora is located on Melbourne's northern fringe (scale is approximate).....	15
<b>Figure 5:</b> WestWyck is located in East Brunswick.....	17
<b>Figure 6:</b> Key social enablers of resilience.....	38
<b>Figure 7:</b> Managing the trade-off between resilience enablers when designing for future operating conditions.....	49

## List of tables

<b>Table 1:</b> Energy and water system faults at Aurora and WestWyck as identified by interviewed stakeholders and householders.....	27
<b>Table 2:</b> Key technical enablers of resilience identified at Aurora.....	31
<b>Table 3:</b> Key technical enablers of resilience identified at WestWyck.....	32
<b>Table 4:</b> Summary of enablers.....	51

# 1. Key findings

The Resilient Urban Systems project has sought to understand how community-scale energy and water systems influence community adaptive capacity and resilience to climate change. Because this pilot project focused on only two case studies, findings are preliminary and should be treated as indicative. Further research, involving case studies across a broader and larger range of contexts, is needed to verify and test their validity. Six provisional findings are drawn relating to infrastructure design for climate change adaptation.

**Finding 1:** The resilience of community-scale infrastructure systems, such as water supply or energy generation, results from the interaction of diverse and context specific technical, institutional and social ‘enablers’.

**Finding 2:** Climate change poses few direct short-term threats to the local energy and water systems examined. However, both developments also depend on larger energy grid and reticulated water systems subject to indirect threats from climate events and future change.

**Finding 3:** Climate adapted infrastructure requires integration of technical, institutional and social resilience. Where uncertainty exists regarding future operating conditions, institutional, and social enablers may prove to be particularly important in ensuring resilience.

**Finding 4:** There has been an emphasis on technical resilience in the design of novel infrastructure systems at the expense of community and institutional enablers of resilience. This may place certain communities at risk from climate change and other disturbances, particularly where social capital is weak, and where system designers and investors have limited on-going responsibility for the functionality of systems.

**Finding 5:** Victoria’s current regulatory landscape poses few direct barriers to the replication of the systems examined but it does restrict innovation in community-scale infrastructure systems.

**Finding 6:** Community scale systems potentially provide both advantages and limitations over conventional centralised systems. Integrating centralised and distributed system models may maximise advantages and minimise limitations associated with both models. An integrated system comprising linked provisional infrastructure at multiple scales may offer the best way to build resilience at all levels - from resource producer to resource user.

## 2. Introduction

In the last three years, a number of record-breaking events have demonstrated the vulnerability of Australian communities to the impact of extreme weather. Tens of thousands of people have been affected and the cost to business, insurers and the public is estimated to have exceeded \$15 billion (Dobbin and Dowling, 2009, Ker, 2009, Dumas, 2011, State Government of Victoria, 2009). Many of the most severe social and economic impacts resulted from disruption to infrastructure systems.

The scale of these impacts illustrates how modern societies such as Australia are dependent on the continuous function of critical (energy, food and water) infrastructure. The design of many of these systems is based on projections of historical trends in climate variability and pre-date contemporary understanding of climate change. Climate models are not only projecting an increase in the intensity, frequency and duration of extreme weather events over the coming decades, they also indicate a growing likelihood of low probability/high impact ‘outlier’ events (Nicholls, 2008). Given the longevity of critical infrastructure and the long investment pay-back times they require, investors, engineers and utility managers face a key challenge in knowing how existing and emerging less- and de-centralised infrastructure systems might minimise or exacerbate community vulnerability to climate change and other disturbances. This challenge is made particularly difficult by the uncertainty surrounding predictions of future climate change and its impacts (Ben-David, 2010).

With the increasing appearance of less- and de-centralised (water and energy) infrastructure systems as part of new residential developments, it is especially important to determine how these systems affect the resilience of Victorian communities.

### 2.1 Our definition of resilience

The resilience of any energy or water system (which includes the individuals and communities reliant on the service) is indicated by the degree of disturbance it can absorb, adjust to or avoid without losing its essential functions or identity (Walker and Salt, 2006, Folke et al., 2003, Holling, 1973, Handmer and Dovers, 1996). Critically, as understood in this project, resilience is not just the ability to return to a former state post-disturbance. It also incorporates the concepts of adaptive capacity and transformation (Walker et al., 2004). Transformation reflects a very high degree of resilience, despite the loss of original system structures, functions or identity, provided this process is deliberate and results in desired conditions.

A number of researchers and system designers (including the authors) have questioned the resilience of conventional infrastructure systems under conditions of resource scarcity and environmental and social uncertainty. They argue that the features and characteristics that enable ‘centralised’ infrastructures (including energy and water systems) to provide consistent, reliable, low-cost and high-quality generic services to large numbers of people are an advantage only under conditions of stability (Biggs et al., 2010). Under conditions of change and uncertainty, these systems can be brittle, or ‘easily shattered by accident or malice’, thereby reducing community resilience (Lovins and Lovins, 1982, Auld, 2008, Biggs et al., 2010). Lovins and Lovins further explain: *‘Our reliance on these delicately poised energy [and water] systems has unwittingly put at risk our whole way of life’ (ibid).*

System brittleness can also be introduced by system users, as an unforeseen consequence of the aim to perfect the performance and maintenance of a system to such a degree that users rarely experience any kind of change. In this situation, when change does happen, it is so outside the range of users' experience that the social consequences can lead to even greater disruption and tip a disturbance into system collapse (Chappells and Shove, 2004, Trentmann, 2009). For example, during a breakdown of the Hong Kong Mass Transit Railway in 1996, what started as a track-circuit defect escalated to a serious incident involving hospitalisations simply due to the reaction of large numbers of passengers pressing alarms (Trentmann, 2009). These passengers had become normalised to a system where 99.9 percent of journeys took place with no incident (ibid.). The reverse has also been found, where households or communities are so accustomed to coping with a repeated event within a tolerable level that they are unable to foresee an event of a magnitude that they may not cope with. This has occurred in Canada where communities normalised to routine flooding of a river were unwilling to respond to repeated warnings of a serious flood that they were unprepared and unable to cope with (ibid.). Resilience, therefore, does not result from the technical perfection of a system, or from better communication, but rather from facilitating, encouraging and maintaining the capacity of all elements of the system to adapt. In the types of (socio-technical) systems analysed in this report, resilience arises from the nature of, and interactions between, technical, social and institutional elements within the energy and water systems. Each of these three domains can work individually or together to increase or decrease a system's resilience.

*Why use this approach?* Consider a system that delivers water from an inland reservoir to wash clothes in someone's home. In this case, a specific disturbance (a fire in the catchment) might contaminate the water causing the system to fail in its core function (to deliver water for washing clothes). Conventionally, resilience might be built into this system through various technical means such as improved fire response equipment, links to another supply reservoir, or use of a treatment facility. However effective these responses may be, a purely technical approach to understanding system resilience is unnecessarily narrow and can miss opportunities for achieving more effective or more efficient outcomes.

System resilience can be demonstrated and enhanced in alternative ways. In the example just given, changes in technical arrangements might also involve the addition of a local water source (such as a rainwater tank). But doing so will also require a change in the institutional and social characteristics of that system: institutional—because a new, more localised governance arrangement will be needed to ensure the tank is maintained; and social—because the laundering practices of householders may need to adapt to the new water source. Alternatively, resilience might be increased by a change in the social acceptance of how frequently clothes need to be washed, with a subsequent reduction in water demand for washing. A more significant shift in the system might also occur, with householders adopting a waterless form of clothes washing. In this example, the technical, social and institutional nature of the system is completely transformed, while the desired outcome is maintained.

The key notion in our conception of resilience is the capacity for adaptation (technical, institutional or social) to maintain a desired outcome **or** to change the nature of the desired outcome in response to a disturbance.

In some circumstances, adaptation can occur that ameliorates certain conditions while exacerbating others. Such 'maladaptation' is typically associated with decisions that address a short-term problem while undermining efforts to address the bigger issue (Barnett and O'Neill, 2010). For example, a householder may decide to install an air-conditioner in response to heatwaves, which inadvertently increases the burden on the electricity grid during periods of peak demand, increases the use of energy resources and reduces the householder's tolerance to variable indoor temperatures (De Dear and Brager, 2002, Wilkenfeld, 2004). In this case, the air conditioner is a maladaptive response to the problem of heat discomfort.

## 2.2 Emerging infrastructure models

While the operating conditions for future infrastructure systems may differ from the past, the range of system designs available to current decision-makers is expanding. Shifts in social norms, market conditions and technical capacity over the last two decades have seen the emergence of varying forms of infrastructure, including those providing energy and water services.

These systems are diverse and potentially disruptive to conventional infrastructure. At one end of the scale are systems that may support a single household. Greywater systems, rainwater tanks and solar photovoltaics are some common examples. Above this scale lies a rapidly growing (market driven) range of technical systems suited to community, industrial facility or precinct scale. Water recycling ('third-pipe'), stormwater collection and small solar thermal and cogeneration systems are just some examples.

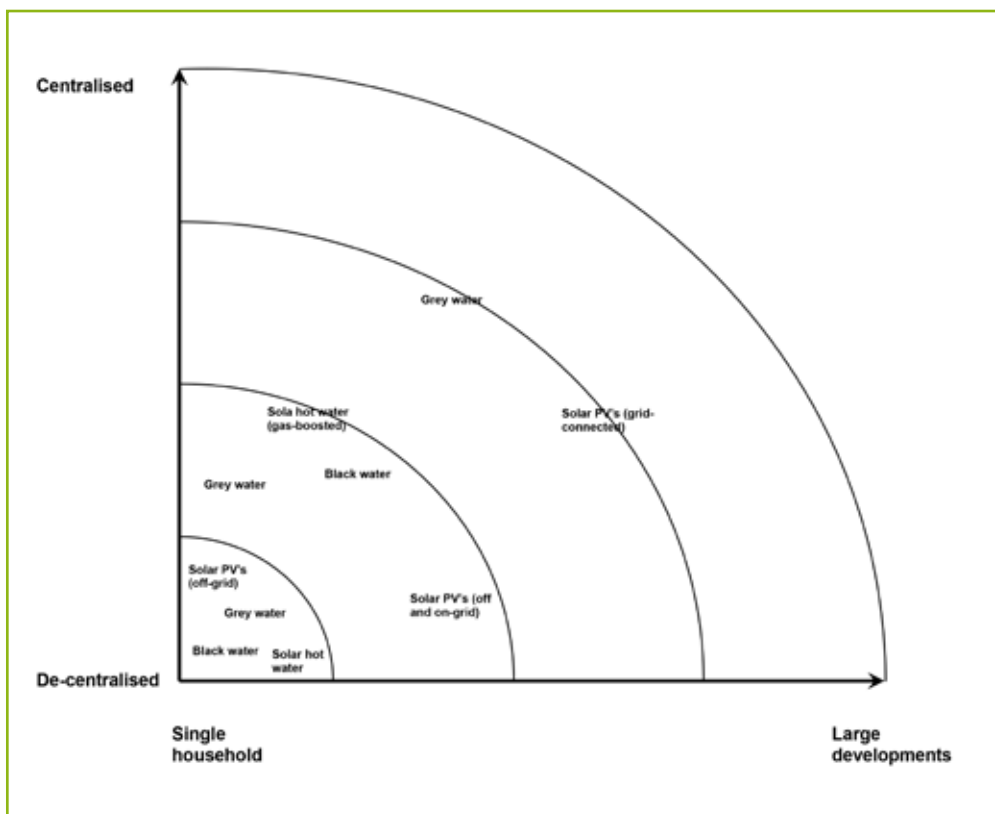


Figure 1: Spectrum of water and energy systems

The growing availability of 'alternative' energy and water systems is important in the current context. Existing systems are demonstrating significant weaknesses (even brittleness), adaptive strategies to climate change are needed, and infrastructure investment is required to meet increasing demand. In a recent report on Melbourne's water resources, the State Government recognises a need for new ways to manage water resources to address the increasing strain being placed on existing infrastructure from:

- A rapidly growing population;
- Pressure on the natural and built environment from population growth;
- Increased climate risk and variability;
- The need for safe and secure water to support resilience and liveable communities; and
- Growing community concern about the rising costs of water.

(Victorian Government, 2011).



Changes in social values and an increased focus on demand management are helping to re-define infrastructure systems with a shift away from the traditional 'one-way' relationship between service providers and end-users. Increasingly, people are experimenting and identifying as small-scale producers. This form of social innovation is not unique to the energy and water sectors and mirrors a wider shift towards public participation in, and control or co-management of, what used to be industry or corporate domains. In contrast to traditional models of provider-user relationships, where user consumption is seen to be a function of regulated information, prices and incentives, de-centralised energy and water systems often involve users playing a role in co-production and co-management. This is encouraged through greater interactions between environmental agencies, competing water and energy utilities and civil society as co-participants in decision-making (Sofoulis and Strengers 2010; Brown et al 2009).

Many of these shifts are being anticipated at the State Government level, particularly in reference to water resources where new principles designed to underpin water reform priorities include:

- Social equity;
- Cities and towns planning to meet their own water needs;
- Engaged and empowered communities;
- Water resource and services valued, managed and used efficiently; and
- Transparent, adaptive and flexible decision-making involving consideration of all options.

(Victorian Government, 2011)

## 2.3 Linking infrastructure design with adaptive capacity

A future in which smaller 'community-scale' infrastructures of provision are common would have important implications for climate change adaptation in Victoria. If more communities become reliant on de-centralised energy and water systems, individual and household relationships to these systems could be expected to shift from relatively passive consumption toward more active engagement in system management, with the development of knowledge and skills that build system resilience and community adaptive capacity. Of course, not everyone will make that transition immediately, but changes could be expected over time.

Where users can more easily exert influence over the technical, operational, or institutional aspect of systems of provision, other connections between infrastructure design and community adaptive capacity are likely to appear. For example, studies have shown that people reliant on localised but grid-connected energy systems are often more conscious of how and when they use electricity, and have a lower energy use compared to people solely reliant on the mains grid (ATA, 2007). Notwithstanding the effect of self-selection, this has positive implications for delaying infrastructure investment and reducing the frequency of blackouts. Conversely, a shift to community-scale systems may also require stakeholders to shoulder new responsibilities for which they are not prepared. For example households may be partly or wholly responsible for technical and operational management of localised infrastructure systems which would require new forms of support for access to financial, physical or technical expertise. In summary, despite their promise, it is unclear how community-scale, less-centralised energy and water systems will function over time and under duress from climate change and other types of disturbance.

As alternative systems emerge in new developments, can they help to increase the resilience of Victorian communities to climate change and other disturbances, and if so, how? Addressing this question will assist urban planners, developers and communities understand the risks and advantages that come with a decision to apply novel solutions to emerging energy and water challenges.

## 3. Aims and approach

The Resilient Urban Systems project is a response to the complex challenge of ensuring energy and water infrastructure systems are adapted to climate change and that they minimise rather than exacerbate community vulnerability. This research project is a pilot exercise that considered the alternative energy and water systems of two selected communities as case studies to identify key issues, challenges and opportunities for improving the resilience and adaptive capacity of Victorian infrastructure. The investigation was framed around understanding different designs for energy and water systems and adaptive capacity of Victorian urban communities, and what policy innovations and initiatives would encourage the spread of long-term resilient systems in the short term.

Objectives of the Resilient Urban Systems project:

- A. Identify existing examples of innovative/emerging energy and water supply systems, and define the organisational arrangements surrounding these systems.
- B. Determine how selected Victorian urban communities and households are adapting (or maladapting) to innovative/emerging energy and water systems, and the implications for system resilience.
- C. Examine how these systems were developed, the stakeholders involved, and the policy initiatives and institutional arrangements that might encourage innovation and uptake of resilient systems elsewhere.
- D. Assess the policy and technical opportunities, innovations and constraints that might arise in expanding the scale of resilient systems in Victoria's urban communities.
- E. Develop preliminary criteria to assist policy makers in evaluating the resilience of new urban system options, taking into account the role of social adaptation.

The outcomes of this research are intended to inform the development of a more extensive analysis to address the above objectives. The pilot project was intended to provide sufficient indicative data that it could inform the planning of resilient urban systems by Victorian governments, agencies and programs *and* identify critical areas for more detailed research.

### 3.1 Methods and approach

Resources limited the research to two pilot case studies: Aurora and WestWyck. In studies of urban socio-technical systems, there are so many variables that a controlled comparison is meaningless. However, empirical research can provide useful comparative evidence when case studies are examined in detail in their own context. Ideally, urban socio-technical relations should be studied longitudinally, to allow comparisons to be made over time, for example, 'before' and 'after' particular system changes occur.

It is important to note that while both systems have been in place for similar periods of time (less than a decade) they do exhibit key differences beyond the configurations of alternative energy and water systems. Firstly, Aurora is a much larger scale development and secondly, it is established in an outer fringe setting. In contrast, WestWyck is within an inner urban setting, and is occupied by households who in general are at more established life stages. These and other differences limit direct comparisons of performance and indicate the need for further research involving more cases from which to generalise patterns and findings.

Research for this report was conducted between May 2010 and May 2011 and occurred in four phases as described below and summarised in Figure 2.

**Phase 1** – Potential case-studies in Victoria were identified using an online survey and two case studies were selected for further analysis. A review of resilience literature was conducted to frame the case study analysis.

**Phase 2** – Twenty semi-structured interviews were conducted with 16 households across both sites. These were conducted over summer with the intention of eliciting residents' experiences adapting to high temperatures and water stress. Householders were initially contacted anonymously <sup>1</sup> via a letter describing the research and inviting interested participants to contact the researchers directly. Households were offered a \$30 voucher for Coles/Myer in exchange for their participation if selected.

Due to the large number of responses from residents, a follow-on selection process was conducted to ensure we obtained a representative range of participants in terms of gender, age, education, cultural heritage, family status, years in the Australia, years in the community, owner/renter, type of work and work status.

Householder interviews were recorded, transcribed and analysed using NVivo qualitative analysis software. All interviewees are de-identified and non-identifying codes are used for the purposes of analysis and reporting on project findings. Where excerpts from the householder interviews are used in this report, householders are identified as A1 to A13 for the 13 interviewed at Aurora, and W1 to W7 for the 7 interviewed at WestWyck.

**Phase 3** – Multiple site visits to both developments. Nineteen semi-structured interviews were conducted with institutional stakeholders. Interviewees were identified from the following organisations: water utilities, local councils, body corporates, developers, state government departments, community and other organisations.

Stakeholder interviews were transcribed and documented for analysis. All interviewees are de-identified and non-identifying codes (S1 – S19) are used for analysis and reporting.

**Phase 4** - Research findings from Phases 2 and 3 were collated and analysed for the development of preliminary assessment criteria to evaluate resilient urban energy and water supply systems. Presentation of outcomes and recommendations to relevant public, private and community stakeholders following the completion of this report is also part of this phase.

Approval for all qualitative data collection was granted by the RMIT Human Research Ethics Committee in June 2010.

Researchers from the Centre for Design and the Victorian Eco-Innovation Lab (VEIL) worked closely and collaboratively to integrate the outcomes of project components. They also liaised with key stakeholders and members of the reference group to ensure project outputs were relevant in content and appropriate in format to their policy needs.

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<sup>1</sup> Three members of the WestWyck Owners' Corporation controlled the initial research process. These individuals were contacted directly and interviewed prior to the letter being approved for distribution to all households.

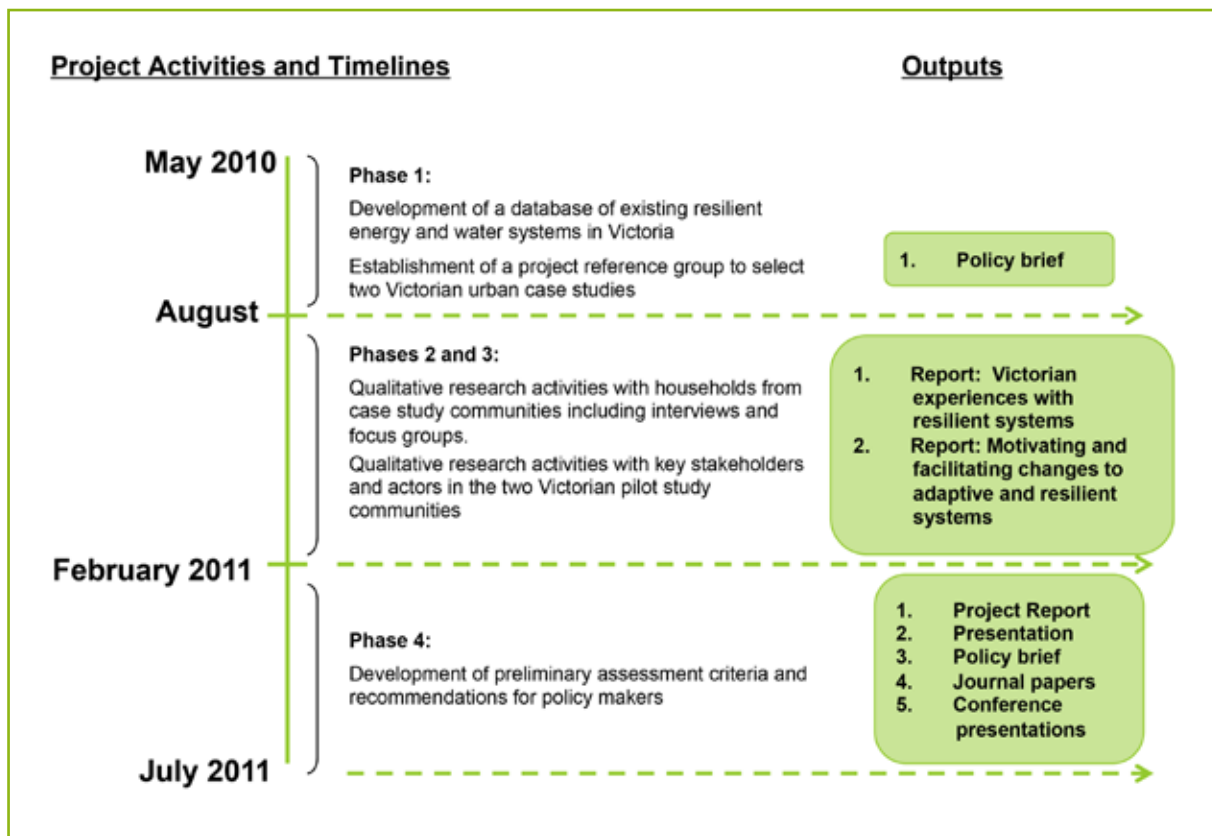


Figure 2: Project activities and timeline

### 3.2 Collaboration and support

The core research team from Centre for Design at RMIT University and VEIL at the University of Melbourne met regularly throughout the project. They also convened two meetings with the broader project team in the early phases. RMIT's School of Civil Environmental and Chemical Engineering were involved in several separate meetings and communications regarding the technical features and evaluation of the systems. Members of the VCCCAR project team 'Framing multi-level and multi-actor adaptation responses in the Victorian context' provided valuable input to the project's policy briefs. The project reference group, established as part of Phase 1, was included at each phase of the project and provided valuable input particularly during a forum in August 2010 for case study selection. This group was also given the opportunity in June 2011 to provide feedback and comments during the initial development of the final report. A draft of the final report was provided to VCCCAR and the Implementation Committee in October 2011 for review and comments. A subsequent iteration of the report was provided to VCCCAR in November as part of VCCCAR's 'facilitated review' process. VCCCAR approved the final report in December 2012 and the second and final policy brief was submitted later that month.

Several members of the project reference group are part of VCCCAR's Implementation Committee. The group provided the committee with regular progress updates, which provided additional opportunities for stakeholders to offer valuable input to the project as it developed.

### 3.3 Socio-technical framework

The method for assessment and analysis is structured around two frames of understanding socio-technical system resilience. The first explicitly positions adaptive capacity as one ingredient of system resilience with the capacity to re-shape, build or undermine a systems' resilience. This framing is critical in the context of this project because it recognises that the integrity of infrastructure systems is partly dependant on the capacity to adapt, but also that, through adaptation, the system itself can change (e.g. in expectation of new threats).

The second framing (Figure 3) recognises that infrastructure systems function through interactions between people (users), physical systems (technical hardware) and institutions (governance and management arrangements) and that elements within each domain can support or undermine system resilience.

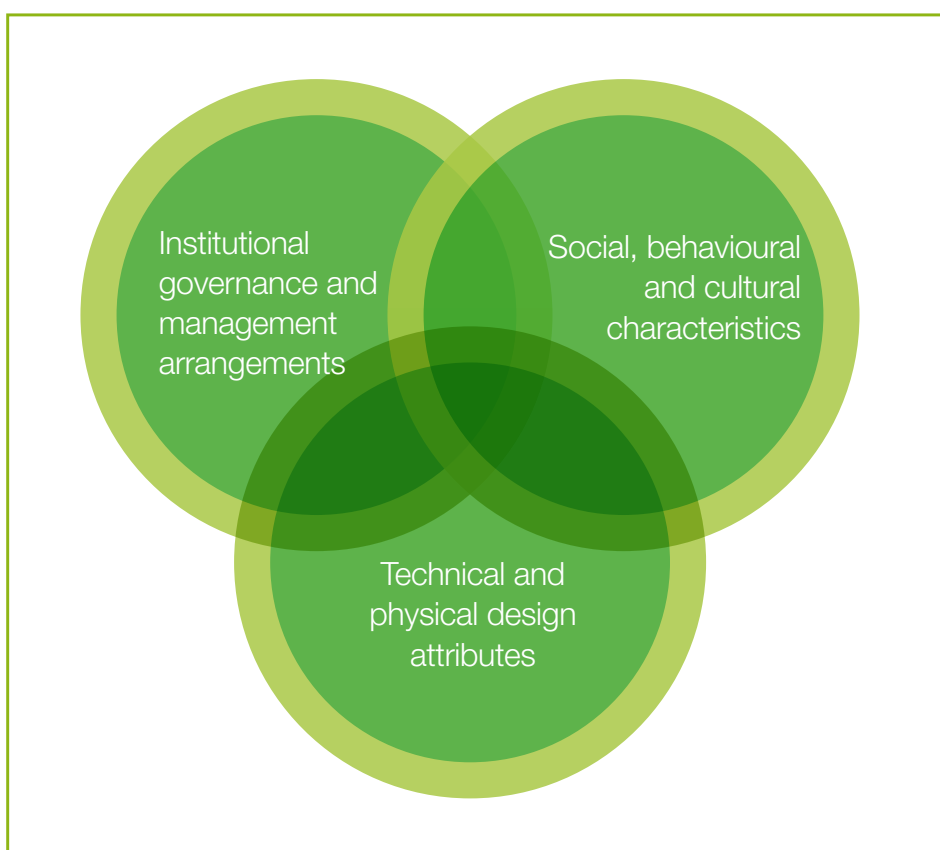


Figure 3: Framework for socio-technical system resilience

## 4. Results

This section describes the results of the three main data collections phases of this research, and provides the context and foundation for the subsequent analyses and final project outcomes.

A summary of the case study selection process in Section 4.1 is followed by a description of the two sites and their systems (Section 4.2). Sections 4.3 and 4.4 present the high-level outcomes of the householder and stakeholder interviews respectively, with reference to the original objectives of these phases. More detailed and integrated analyses of these data contributed to the discussions of the broader theme of resilience, and the formulation of key project findings and preliminary criteria (Section 5 and 6).

### 4.1 Innovative energy and water systems in Victoria

Phase 1 research led to the compilation of data on 31 alternative systems in Victoria. However, the majority of submitted projects were either:

- Non-household (related to either business or public-space/amenities)
- Single-household
- Demonstration sites
- A concept or product still in development or seeking support trial.

Furthermore, most were not operational and not expected to be so for at least a year. It should be noted that many of these projects might be worthy of follow-up in relation to future research in this area. Through the project reference group, the two pilot projects selected for further study – Aurora Residential Development and WestWyck Village – showcased respective examples of a development-led and a community-led response.

Aurora, the development-led project, serves 8000 households in the outer Melbourne suburb of Epping. WestWyck Village is a community-led project serving 12 households in the inner Melbourne suburb of West Brunswick. These contrasting projects provided an opportunity to explore system examples at different ends of the spectrum in terms of nature, size and system ownership. A more detailed account of the methods and outcomes of Phase 1 is available from the project website: [www.vcccar.org.au/content/pages/resilient-urban-systems](http://www.vcccar.org.au/content/pages/resilient-urban-systems)

### 4.2 Details of case studies

#### 4.2.1 Aurora

Aurora is an urban development in Epping North, on the northern fringe of Melbourne's suburbs (Figure 4). Aurora was launched in 2006 and is due for completion around 2025-2030. When completed, the development will house over 8000 allotments and around 25000 people (VicUrban, 2011).

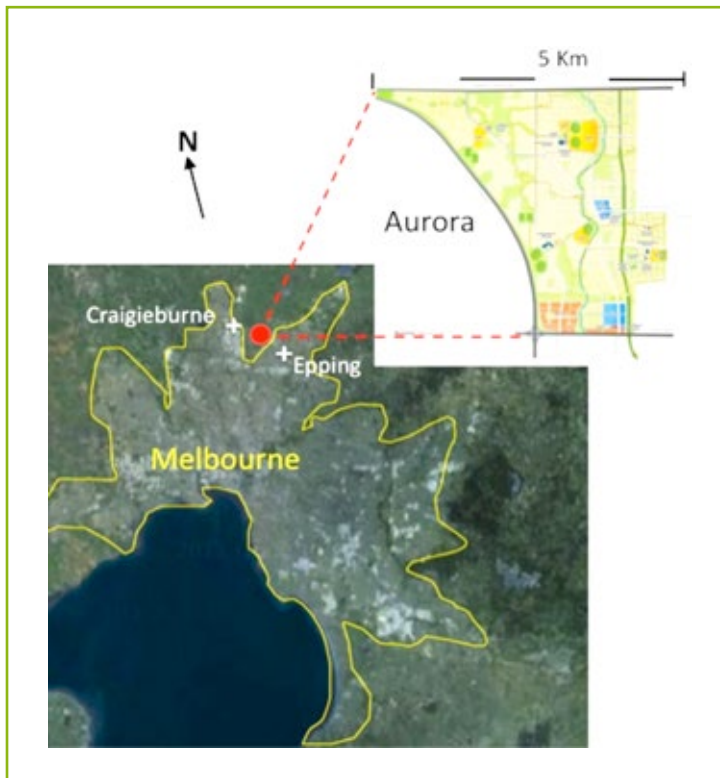


Figure 4: Aurora is located on Melbourne's northern fringe (scale is approximate)

#### 4.2.1.1 Overview of energy and water systems

All residential allotments at Aurora are supplied with the following energy services:

- Electricity and gas supply to individual allotments
- Low-energy street-lighting
- Mandatory gas-boosted solar hot water units.
- Passive housing designs

**Electricity and natural gas** are delivered through mains distribution systems and are reliant on off-site resources and management. **Hot water** is delivered on-site for each home from roof-mounted, gas-boosted, solar hot-water units. These are reliant on mains gas supply for assisted heating and the mains reticulation network for potable water. **Passive housing design** is required as part of Places Victoria's 6-star energy rating mandate for all homes. Passive features are largely defined by the builder at the design stage. After building completion, home owners have sole responsibility for using, maintaining or changing passive design features. Places Victoria sought to educate existing residents, primarily through providing written information on ways to maximise and enhance passive design features.

All residential allotments at Aurora are supplied with the following water services:

- Potable water supplied to individual allotments
- Wastewater collection and treatment
- Supply of recycled 'Class-A' water, delivered via a 'third-pipe' network for non-potable water
- Stormwater collection, filtration and infiltration throughout Aurora with water sensitive urban design (WSUD) features



Water is supplied to each allotment via the mains water distribution network. Aurora relies on **potable water** supplied by the local water utility which, as a retailer is, in-turn, reliant on distribution networks and catchment reservoirs controlled by Melbourne Water. **Wastewater** is collected and pumped to a nearby treatment plant where it is processed and filtered to 'Class-A' standard, then pumped back to Aurora via a dedicated 'third-pipe' distribution system and plumbed into houses for toilet flushing and outdoor use. **The recycled water** infrastructure is designed to function independently from wider sewerage treatment and reticulation systems but is connected to, and can draw on, both if necessary. The recycled water network also supplies multiple access points around Aurora for irrigating public green areas.

**Stormwater** management is the responsibility of the local council – principally the maintenance of WSUD features constructed throughout Aurora. These features consist of landscaped and vegetated infiltration swales and basins, drainage areas and constructed wetlands. Aurora's WSUD features are developed in stages synchronised with hard-surface construction prior to housing construction. Once construction is complete, and in accordance with common practice, responsibility for maintenance switches from the developer to the local council.

Several factors shaped the design of services at Aurora. At the time of inception, Aurora lay outside the catchment area of the nearest mains sewerage distribution trunk. Connecting potable water to the site was possible but access to sewerage treatment was not. Rather than waiting for the sewerage lines to be extended, the developer chose a more innovative approach to water treatment. Other factors also played a role in shaping system design. One consultant noted how *'one of the bases for going down this path was climate change'*, leading to decisions on system designs intended to reduce the development's carbon footprint and increase its ability to handle climate change impacts. The focus on mitigation influenced:

- Strategies used to reduce construction waste to land-fill;
- The use of low-energy street-lighting;
- The decision to mandate solar hot water heaters for each house;
- The six-star energy performance rating required for all homes (above the then mandated five-star); and
- Strategies aimed at reducing the embodied energy of buildings.

Places Victoria and consultants were very conscious of risks posed by climate change and concerns about drought and future water scarcity directly influenced their adoption of WSUD features and the 'third-pipe system' for recycled water. The ability to 'drought-proof' Aurora using innovative approaches to water services was also seen by Places Victoria as offering an incentive to potential buyers compared to other sites as well as helping to reduce off-site nutrient pollution.

#### 4.2.2 WestWyck

WestWyck is a 12 household 'eco-village' development in West Brunswick, Melbourne (Figure 5). The development is situated on the site of a former school and incorporates the pre-existing school building. Development stage one, comprising five townhouses, seven apartments and a shared living space, was completed in 2008. Construction on stage two is yet to commence. All following descriptions and analysis relating to WestWyck are based on an assessment of stage one only. At the time of writing WestWyck's population was 32.



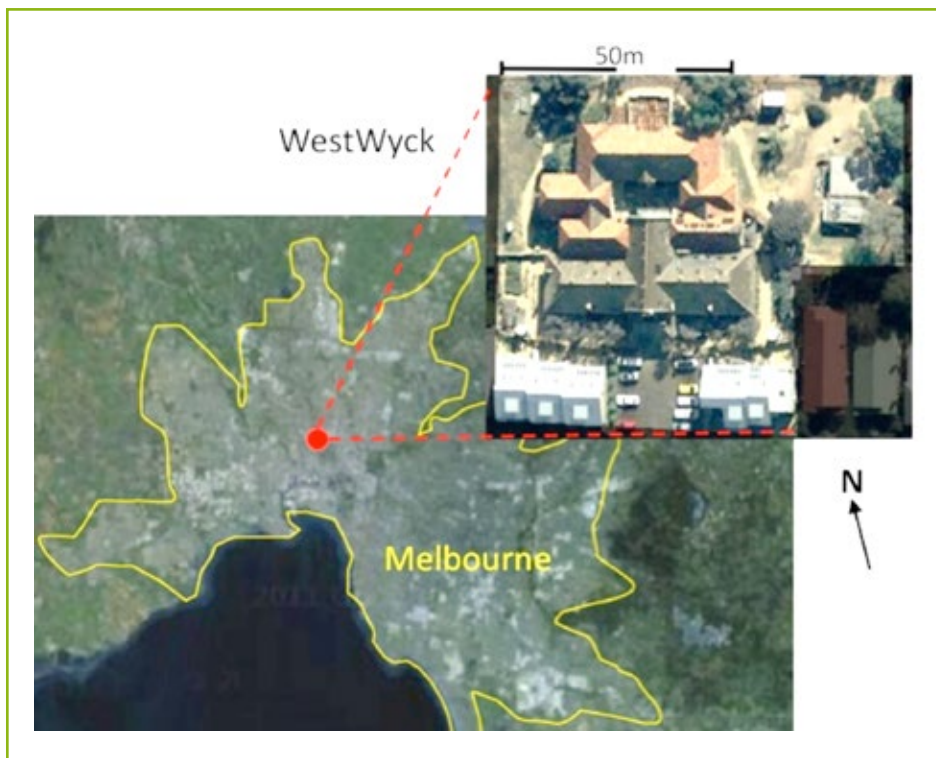


Figure 5: WestWyck is located in West Brunswick

#### 4.2.2.1 Overview of energy and water systems

The following energy systems and services are available at WestWyck:

- Mains gas and electricity
- Solar hot water and space heating
- Solar photovoltaic PV electricity
- Passive thermal design

Citipower and SP AusNet are responsible for managing the **electricity** and **gas distribution** networks (respectively) that supply WestWyck. WestWyck Owners Corporation (WOC) is responsible for distribution of electricity and gas on-site. All five townhouses and three of the seven apartments have their own **solar hot water** units, supplied by rainwater collected onsite. Individual units consist of 12 evacuated tube collectors and 250L water storage tanks. The four remaining apartments share a single hot water system. All solar hot water units are linked to **hydronic space heating** systems backed-up by continuous flow boosters. All systems are connected to and reliant on mains supplies of gas and reticulated water for back up. WOC is responsible for maintenance of the hot water and hydronic heating systems.

The five townhouses and four of the apartments are fitted with **photovoltaic** (PV) panels, with inverters and two-way meters monitoring electricity flows to and from the mains grid. PV arrays are managed by WOC and services (for maintenance) are currently contracted to Moreland Energy Foundation (MEFL).

Most **passive design features**, including northern orientation, selective fenestration, high internal thermal mass and building shell insulation, are built-in and cannot be altered. However a number of features, particularly the use of shading devices and ventilation, can be adjusted to influence internal temperatures. Residents are given education-packs explaining how to maximise the efficiency of passive design features.

WestWyck residents rely on the following water systems and services that are managed and maintained by a combination of institutions and stakeholders:

- Centralised reticulated water supply
- On-site greywater treatment and reuse
- On-site blackwater treatment
- Rainwater collection and use
- On-site storm water collection (WSUD)

**Reticulated potable water** is supplied to each allotment via the mains water distribution network. The retail water utility has responsibility for water quality and water provision to the water meter at each allotment.

**Grey-water** produced on site drains to a shared treatment system. Greywater is treated to 'Class A' standard for use in household toilets, laundries and on gardens. A pressurised tank is used to store treated water and has a manual back-up switch for mains supply if treated grey water fails quality tests or runs low. WOC is responsible for on-going operation with responsibility for maintenance, upgrades and monitoring contracted to a commercial operator.

All **black-water** produced on site drains to a shared treatment system. From here a small (but unknown) volume of accumulated solids is pumped daily to the mains sewer. Clarified liquid drains into sealed and vegetated evapotranspiration beds containing plants chosen for their high transpiration rates. Excess liquid overflows to the mains sewer. WOC is responsible for on-going system operation. Maintenance and monitoring is contracted to a commercial operator. The local water utility is also responsible for ensuring the mains sewer exists as a backup for sewerage disposal if the on-site system were to fail.

**Rainwater** is collected from each townhouse and stored in individual 5000L under-deck tanks. Rainwater is also collected from the main apartment building and stored in visible tanks onsite. Water is pumped from each tank to roof-mounted hot water units and connected to external taps. As backup, mains water is also plumbed in and connected via an automatic switch if rainwater supplies run low. All aspects of the rainwater system maintenance fall under WOC's responsibility. The WestWyck site has also been designed and landscaped to minimise stormwater runoff following **WSUD** principles. This is achieved through a combination of rainwater collection and reuse, porous surfaces, communal rain-gardens and infiltration beds to collect excess rainwater. WOC is formally responsible for on-going maintenance of WSUD features. However, a number of residents are active in providing many of the maintenance services required (independent of any WOC decision) such as seeding garden beds and infiltration areas.

The energy and water systems used at WestWyck reflect the developers' vision of an eco-village designed on environmental and community ideals. Initial development concepts were strongly influenced by concerns over unsustainable resource consumption and a belief in the need to reduce the environmental impact of urban developments. These concerns translated into an emphasis on maximising localised production and reducing demand on external resources.

Initial concepts were not always feasible and current system configurations are the result of a multi-year learning and adaptation process. For example, despite initial aims, water self-sufficiency was later considered too ambitious. Nevertheless, designs were influenced by concerns over environmental conditions consistent with climate change projections, particularly drought.

## 4.3 Living with alternative systems

Phase 2 consisted of qualitative research involving households in the pilot study communities. A total of 20 householders were interviewed at 16 households in WestWyck and Aurora. Interviewers were focused on understanding:

- Adaptive (and maladaptive) practices and strategies households and communities have developed in response to changes to systems of electricity and water provision;
- Householders' perceptions of adaptation and resilience in relation to energy and water;
- How householders perceive and manage risks and vulnerabilities within those systems; and
- How vulnerabilities could be reduced and resilience improved within those systems.

### 4.3.1 Householder backgrounds

A preliminary understanding of householders' backgrounds and reasons for moving into their current home provides context for the subsequent discussion and outcomes of this research.

Aurora: A total of 13 householders were interviewed at ten households, 12 of whom were under 54 years of age and eight of whom were under 45. Nine of the ten households had moved from suburbs within a 15km radius of Epping, some closer, and six households were families with young and school age children. Only four of the ten households described themselves as being of Australian heritage. The remaining six included Indonesian, Macedonian, Greek, Dutch, Italian and Canadian.

At Aurora, householders were attracted by the affordability of the homes, the proximity of parks, play areas and schools for children, and familiarity with the area, with family and friends often close by, as the following quotes illustrate:

*"Yeah, because (it's) closer to school. And then we look around (for) the closest and (most) affordable for us" (A11)*

*"The predominant decision was the price." (A13)*

*"It was a six star energy rating, that was one of the drawcards you know with electricity and... they were saying it was going to be cheaper, all our bills will be cheaper." (A6)*

*Affordability I would have said. Initially it would have been the only... house and land package – because I grew up in Epping – that would have been affordable" (A1)*

*"More about the... gardens and the playgrounds and those sorts of things because I think that's a big thing for people who come here." (A9)*

*"I wanted it to be close to family because we've got a little boy and my mum takes care of him a lot. So that was another thing definitely." (A3)*

*"We thought this was going to be a good place for the kids to grow up." (A5)*

WestWyck: In contrast to Aurora, five out of the seven householders interviewed at six households in WestWyck were over 55 years of age. Only two households had moved from neighbouring suburbs and there were no children resident at any of the interviewed households. All interviewees at WestWyck, bar one, describe themselves as being of Australian, New Zealand or Anglo cultural heritage.

Interviewees were attracted to the community by its alignment with their lifestyle values and ethics, accessibility (inner Melbourne) and the social component of this 'instant neighbourhood' (W7). As these residents explain:

*"It encapsulates a lot of my values." (W4)*

*"We have already invested heavily in ecologically friendly communities elsewhere... We wanted it to be a location in which transport would be fairly close to where we would need to work." (W2)*

*"I had worked in a architecture firm that specialised in doing green architecture so I was kind of familiar with a lot of the concepts and the hardware that goes with a house like this, and I've always felt that buildings needed to be as sustainably designed as possible, not only for minimising energy use but also for comfort levels for people." (W6)*

Residents of WestWyck tended to come from a background of high-level knowledge and practical engagement with sustainability/ecological concepts. This is in contrast to householders at Aurora, none of whom indicated that they had lived previously with alternative systems or according to sustainable/ecological values. Sustainability features were mentioned as a reason for moving only in relation to the lower utility costs promoted by the developers. Although some householders were aware and supportive of the principles incorporated in the Aurora development, interviews suggested that this awareness is more recent and less developed:

*"A couple of people, our neighbours, they also like the idea of all these energy saving things, I'm not sure whether that's the general idea here in Aurora though." (A3)*

*"Learning about recycled water and... solar power gas boosted hot water and, you know, sustainable building, and sighting of the, the houses on the blocks and what not. Oh okay, I was in like Flynn." (A7)*

The backgrounds, life experiences and family status of interviewees at each case study location are very different and will influence the ways that household practices are configured, how they have changed, and attitudes and responses to resilience.

### 4.3.2 Changes in practices

This section includes adaptive and maladaptive changes in householders' everyday practices at WestWyck and Aurora, and changes in their interactions with stakeholders as a consequence of living with alternative systems.

For residents of **WestWyck**, living in a community with these systems tended to be described as a continuation, reinforcement or extension of their existing/previous ways of living in terms of energy and water use. These householders were already highly engaged with sustainable practices and so this 'carrying' of previous knowledge and capacity is generally positive. Changes in practices observed at WestWyck have largely been in response to broader design features of the homes in which the systems operate. Overall, these features have a resoundingly positive effect on living comfort:

*"It's not hard to regulate the heating and cooling in this place." (W3)*

*"Certainly lower energy bills and, comfort levels that you don't have to turn on air conditioning and you don't have to have your heating on high" (W7)*

However, certain features produce conditions that require a negotiated response. For example, open-plan and/or lack of venting can make it difficult to retain warmth and achieve passive cooling (especially in upstairs areas). Window size, orientation and the use of materials also affect comfort in certain areas of the home, which in turn affects associated practices. Depending on the interviewees' values, previous experience, capacity and tolerance of discomfort, these features have led to both adaptive and maladaptive changes. Residents also talk about moving downstairs to sleep during prolonged periods of hot weather (adaptive), wearing more clothes for warmth (adaptive), drying laundry on banisters and racks in winter (adaptive), and using stand-alone electric heaters for certain areas and occasions, such as working from home, or when entertaining guests (maladaptive).

*"You say, okay, how many really hot days are there going to be where I'll be sleeping down here in a year? Well, there may be four or five, so far, a year... So you balance it off that way. If that happens to be on a day... where you've got to perform the next morning or whatever, you say, well, hold on, let's go and spend a hundred bucks and go to a motel." (W2)*

*"There is mezzanine third level and that can get a bit cold and we did have a duplex thing [an electric heater] up there so if you were working up there all day in winter you'd need something extra". (W6)*

*"A couple of my neighbours are buying air conditioners. For instance, you got this so called second bedroom right here...it's a glass one...I use it as a study. The one next to us, it gets to well over 50 degrees." (W2)*

*"I have enough money to go out to a hotel [if it is uncomfortably hot]." (W2)*

Priorities around the need for certain appliances, such as clothes dryers and air conditioners appear to be different at WestWyck. However, in some cases, this may be due to the central location and availability of shared resources, as well as financial resources:

*"If I had a load [of washing] and I really wanted to dry them, I'd probably take them to the laundrette". (W3)*

Some changes are a more direct result of the systems themselves. Most householders at WestWyck note that the grey water system causes more discolouration, and occasionally odour, than mains water to the point that one or two residents identify a 'need' to *"scrub your toilet every second day because it does actually, you know it starts to go grey"* (W6). However, most residents do not regard this as a big issue – *"my care factor is pretty low"* (W4) – and the required use of non-toxic cleaning products for the black water system means that the implications of any additional cleaning are minimal.

In terms of influencing the practices of others, WestWyck residents are doubtful that they have had a singular influence on the practices of family and friends, especially as most are already familiar with and often active in, alternative systems and/or sustainability. However, the interest and response is reported as being unanimously positive:

*"Not directly because of me; because I think it's a general build-up of ideas and information and cost effectiveness. "(W6)*

*"Whether they actually carry it out I don't know but yeah everyone usually has a very positive reaction." (W4)*

At **Aurora**, as at WestWyck, changes in the practices of interviewees tend to be in response to broader design features of the home and the way the systems have been designed and installed. In particular, higher levels of insulation and double-glazing have been recognised as creating greater levels of comfort compared to their previous homes, requiring less intervention in the form of additional heating or cooling:

*"I don't even have a pedestal fan or anything... I find I don't need it now, if I keep everything shut, if it's really hot outside, if I keep ... things closed there is no... problem... and with double glazed windows yeah, I swear by them I think they're really, really, really good yeah." (A6)*

*"Because of the shading and where the house is situated, it's pretty good. Also in summer, in winter as well it keeps quite warm because they've got the windows, obviously the sun comes in and warms it up." (A9)*

*"When it's a hot day – I mean, I haven't got any air conditioning in here, I've just got the ceiling fans and that seems to keep the house cool enough. So I think from that point of view, it's a good talking point." (A12)*

*"We're not having to turn the heating on as much, and turn the cooling on as much, especially downstairs." (A5)*



*"So that's where we noticed a big difference in our bills because we're not having heating on or cooling as much." (A6)*

Some features of the systems at Aurora have inadvertently led to adaptive changes in practices. Several householders noted that they have stopped taking baths because the flow restrictor means that it takes too long to fill:

*"We very rarely do baths because it's just, by the time you fill up the bath it takes I don't know how many litres and forever: it takes half an hour to fill the thing up, so we're waiting and waiting and waiting. So sometimes it's just easier just to jump in the shower." (A5)*

*"It just takes too long to actually fill up the tub." (A13)*

However, other features of system design and installation at Aurora do not appear to support resilience. The heating systems used as standard seem able to be zoned, but this is a manual function, requiring the householder to use a chair or ladder, and a broom or something similar, to close off a vent. This requires knowledge (or information provision), technique and action competence. For these reasons, it could be assumed that zoning happens less frequently than it would if it were a more automatic or effortless task:

*"I believe I can but I don't know how to do that." (A1)*

*"No, I don't have the zoning: you can only close them, which we do with the kids' rooms; we actually close them...It's pretty high. Yep. Husband doesn't like it: he's scared of heights." (A5)*

*"We close these if we've got the cooling on, because then the heat would, the cooling would just go straight through the vents and what's the point?" (A6)*

*"No. No. I zone them by shutting a door." (A1)*

One resident indicated that the heating could not be zoned (although it can, manually) and therefore perceives that the ducted system is more inefficient as it heats the whole house. For this reason, they use electric heaters, moved around the house as required:

*"It goes the whole house, so I actually use the hot, electricity heater." (A11)*

The location of vents and fans in the home can also lead to discomfort:

*"Definitely would change these are quite annoying when you're eating especially the heating as well coming straight onto you. And there's three very close together here, they should have spread them out maybe put one over there instead..., we don't have any hanging in the bathrooms and the laundry so we don't have any heating down there." (A2)*

*"This fan was literally 15cm, the blades were literally 15cm from touching each other, so they just put them on top of each other and not spaced it out, so just crazy stuff like that." (A12)*

*"I prefer this as far as the noise factor goes but to be honest as far as the vents I prefer it in the floor, that's just me, because heat rises I find that this is great, it keeps your body warm but the feet are cold" (A6)*

In one case the resident is installing an air conditioner in the bedroom as a result:

*"When I walk in it's this height just for about a metre and that's where they've put it and I find that it doesn't cool down the room enough because it's quite far away and the room has got a very high ceiling. The heating they've put it up on the side of the wall facing into the room. Yeah I don't think it was adequate the vents there are quite inadequate." (A1)*

The use of materials in different parts of the home, particularly upstairs areas also has implications, depending on the tolerance levels, experience and capacity of the residents. One resident notes that they had to install an air conditioner upstairs:

*"Because it's not brick: it's the board upstairs and it just gets that hot, and can you imagine if it's 35, what it would be like up there?" I said to my husband, "Maybe we should live here for a year and see if we need it." But that would have been a mistake because there's no way we would have survived the first summer" (A5)*

Most of the house packages at Aurora included an air conditioning unit, but for three of the homes that didn't, these householders are already planning to have them installed.

In terms of lighting, internal bathrooms that require lighting all times of the day have been remarked on by some householders as examples of inefficient design, and garage lighting that turns on from the doorway with no way of turning it off after departing is a source of frustration for another householder. Once again, several householders mentioned the extended time they have to run the hot water before it heats up. Due to the availability of recycled water for the garden, they have stopped collecting this water, which in any case goes to the grey water system. These are examples of system design scripting householder practices towards maladaptation.

Issues with systems design and installation notwithstanding, many of the residents at Aurora indicate that moving to this development has had a positive effect on their awareness and practices:

*"It's made me more aware about the water and power and resources." (A10)*

*I attended a healthy environment type cleaning seminar...the girl there explained you don't need all these cleaning agents, just water and a damp cloth...and that's what I've been doing." (A13)*

*"I stopped wasting a lot of water, like you know, at the other place I used to take long shower, leave the lights on and that sort of stuff." (A8)*

*"We'll tend to recycle a lot more things now... we didn't realise certain things could be recycled and others not." (A1)*

At both WestWyck and Aurora, where maladaptation can be identified, it is largely attributable to the design of the home, the design and installation of the systems, and how well the interaction of the two has been imagined and integrated with the physical living space.

### 4.3.3 Perceptions of risk and resilience

All twenty interviewed households think that extreme weather events, such as heatwaves, drought, floods and heavy rain, are likely to continue happening in the future, and that their systems will be variously affected (indeed some have already been affected by heat and rain). However, they are almost unanimously of the opinion that there is not much that they can do about it, so there is no point in worrying.

*"If you're worried about things happening, you'd never do anything. And I'm a practical person and if something's going to happen, it's going to happen. Whatever you do, you're not going to change things." (A8)*

*"Severe events, I don't think we know really. But no, I don't worry about." (W3)*

Although perceptions of risk and vulnerability are similar across the two case-study householders, the source of any sense of vulnerability is different. Intrinsic utility costs related to the grey/black water systems were questioned by some householders at both locations:

*"Paying for the service is fine but the actual water usage to me is, you shouldn't have to pay for the recycled water usage if it's no more than what you've used in your normal water... even the neighbours are the same thing. They're like, 'Why are we paying for it twice?'" (A5)*

However, most risks identified by the interviewees at Aurora are attributed to perceived attempts by builders to keep costs down, most especially in the choice of solar hot water systems:

*"When it gets too hot they [solar hot water unit], get overheated and they burst...so when I went to pay for that first one I said would you replace the other one too while you're at it.. and they said no it's not quite fully gone. So I said, I shouldn't have to pay another \$340 for you guys to come out again you know, but I ended up having to so I wasn't thrilled about that." (A13)*

*"It was a cheap house and now I know why, you know." (A13)*

*"They [the builders] have tried to go a little bit cheapo than what they should here, obviously because they want it to be affordable." (A12)*

*"I've learnt things about how they, in order to get their six star rating, you know they can go for the bare minimum of a certain thing in order to get it. And I just kind of think oh well, is the rating system even worthwhile considering that." (A7)*

These comments and experiences are likely to be typical of volume-built housing development in suburban Australia.

In contrast, cost was rarely mentioned as a risk among WestWyck residents, and there is the sense that any faults are dealt with as a community, with costs distributed fairly (although WestWyck and its systems are more established, they still encounter periodic faults and maintenance requirements, as reported even by newer residents). Instead, the most notable system-related risk for residents at WestWyck is the novelty of the systems themselves and the implications of this for system repairs, maintenance, and upgrades. As these householders note:

*"If something goes wrong, you don't have that infrastructure. How many people know how this particular system, hydraulic system works? I'll tell you. There are three people in Melbourne. Full stop. I'm feeling that I am in a situation where I can't fix it, I'm dependent upon getting parts from overseas that may take months." (W2)*

*"It's really reliant upon a number of other people, some of whom we've never met who installed them and they, they know how to work them." (W6)*

*Maintenance contracts make a significant contribution to a greater sense of security in this respect, as well as additional measures to ensure that the community is somewhat buffered against future costs:*

*"It makes you feel way more safe living here than if I was just in a house and didn't know my neighbours. We've got in our body corporate we've just started a sinking fund with the idea that that money would be there to upgrade technology." (W4)*

In relation to the issue of costs, it is relevant to note that there was no difference in income levels between the two groups of interviewees at Aurora and WestWyck. However, their life stage and the location of the development (i.e. more accessible to services and less car dependent) might suggest that residents of WestWyck would have more disposable income.



In summary, interviews suggest that perceptions of risk and vulnerability, including the nature and magnitude of the perceived risk/vulnerability, are a function of householders' perceived capacity to cope in terms of financial, social, technical and institutional arrangements - essentially, what options they feel they have available to them to help maintain their day-to-day practices.

The differences emerging between the two groups of interviewees naturally invite observations about underlying characteristics of the two system models that appear to be contributing to increased or decreased resilience. These differences relate to the technical systems themselves, the institutional arrangements surrounding them, and social dynamics of the respective communities.

Section 5 deals respectively with each of these themes, and uses data from the householder and stakeholder interviews where relevant to illustrate the discussion around factors determined as being important for resilience.

## 4.4 Risk and hazard context

A broad assessment was conducted by the researchers to identify types of hazards and disturbances that might affect energy and water system functions at the case study sites. The assessment included instances where system faults occurred as well as potential risks arising from external factors, with a primary emphasis on threats from climate change. Issues, summarised in Table 1, were identified from on-site visits and interviews with stakeholders responsible for energy and water system functions at various levels, including system managers, maintenance personnel, users and relevant experts.

### 4.4.1 Perceived hazards

At both sites, perceived hazards from a stakeholder perspective stemmed from the use of recycled water (at both developments) and on-site blackwater treatment (at WestWyck). At Aurora, stakeholders (S4; S5; S7) saw health risks as largely managed at the supply end and pointed to a range of mitigation measures, specifically:

- In-line water quality testing mechanisms;
- Periodic validation of 'Class-A' water quality;
- Clearly separating and colouring pipes and outlets connecting to recycled water sources;
- Periodic integrity testing of the recycled water system at various stages during design and construction; and
- Multiple auditing procedures to detect pipe cross-connections during third-pipe network construction phase.

Potential concerns posed by Aurora's third-pipe system relating to the point of end-use (S4; S8; S9) mirror comments by environmental health experts and research into the use of recycled water by the Department of Health (Sarkis and Reid, 2004). At Aurora, end-use risks are managed through multiple measures including:

- Educating residents about the acceptable uses of recycled water;
- Pricing recycled water to reduce the cost advantage of using it for potable water uses;
- Using clear signage of third-pipe systems to reduce the possibility of accidental misuse; and
- Training and auditing plumbers.

At WestWyck, stakeholders also saw on-site water treatment and recycling as posing risks to residents. Developers and experts from the Department of Health interviewed as part of this research considered the on-site black-water treatment system as posing a greater potential health risk to residents than the grey water system (S8; S9). However, they also expressed confidence that a range of technical and institutional arrangements are in place to adequately minimise these, in particular:

- Closed configuration of the blackwater system minimising the potential for residents to come in contact with it;
- The significant experience of the developers and associated confidence that they had the capacity to ensure the system did not malfunction; and
- The location of the developers (living on-site), which ensured their personal interest in the system functions.

In its current configuration, the black-water system at WestWyck has proven highly reliable (S1; S2; S3).

Despite stakeholders perceiving similar risks at both sites, there was a clear difference in how these were managed. For **Aurora**, stakeholders perceived end-user behaviour as the weakest link when appraising the security of water system functions. This drove an emphasis on ensuring quality at the ‘supply-end’.

At **WestWyck** there was less concern about the end-user as a potential problem and a greater awareness of technical faults as the main cause of system malfunction. Compared to Aurora, greater emphasis was placed on ensuring early detection (in some cases involving residents) and the technical capacity for householders/maintenance stakeholders to switch to mains water supply if problems occur (S1; S4; 12).

Interviewees identified the potential prospect of regulatory changes to recycled water use restricting ongoing development of alternative systems. It was suggested that any water system malfunction might provide pressure to tighten, and possibly prevent, further use of recycled water in a residential context.

Shifts in ownership and responsibility over system management were also identified as a threat to the ongoing operation of systems at Aurora. For example, arrangements and responsibilities for the irrigation of urban greenspace with recycled water have, in similar large developments, passed from the developer to the local authority, along with other responsibilities for the maintenance of public space. However, the costs and benefits of such activities can be viewed differently by the developer and the local authority, and the perceived equity in relation to surrounding non-irrigated areas within the LGA can introduce tensions which some interviewees identified as potentially leading to the cessation of irrigation in the development area to fall in line with broader LGA practices.

Interviewees identified a range of instances where energy and water system services and functions did not meet expected standards or desired outcomes. These had variable impacts on the quality of service to end-users depending on people’s expectations, capacity to adapt and capacity to address the issue. Issues reported or experienced are described in the following table.

**Table 1: Perceived problems with energy and water systems**

Note: Caveat – The issues reported in this table are reported as perceived by interviewees. Their concerns have not been verified. The researchers do not imply any flows, faults or liabilities to any party in reporting interviewees' perceptions of these issues.

Location	Issue	Perceptions of primary cause	Impact	Action taken by residents/utility/developer
Aurora	Discolouration and odour of recycled water	Insufficient flushing of the recycled water network (S7; A5; A7; A9; A12)	Temporary loss of convenience, toilet flushing	Residents contacted YVW
	Hot water systems leak during heatwaves	Various, including installation (S16; A5; A6; A9; A11; A12; A13)	On-going reduction in hot-water supply	Residents Contacted building contractors and system manufacturer
	Building thermal performance	Various, including design and construction (S10; S16; A3; A4; A5; A6; A7; A8; A9; A11; A12; A13)	Heating, ventilation, cooling	None
	External recycled water tap does not turn off	Faulty/worn tap seal (A7; A11; A12)	Localised flooding, wasted water, higher bills	Changed tap independently or not yet reported
	Silt blockage of infiltration swales	Runoff, design and/or maintenance (S13; S14)	Localised flooding, failure of infiltration zones	Initial replacement of swales by CoW. Swales now being phased out.
WestWyck	Overflowing rainwater collection systems	Design failure during heavy rainfall. (S2; S3; W2; W5; W6; W7)	Amenity	First-flush system re-configured
	Greywater system malfunctions	Various, including pump failures, treatment malfunctions (S1; S2; S3; S12; W2; W3; W4; W5)	Temporary loss of convenience, Clothes washing, toilet flushing	Residents contacted Owners Corp, and switched water supply to mains
	High level of rainwater seeping into combined Grey/Black- water system	Design and/or installation problem (S1; S2)	Reduced efficacy of treatment process, more frequent overflow to sewer	System design and components overhauled.

There is no evidence of end-users directly causing system performance problems at either site despite this being a key concern of institutional stakeholders interviewed for this project. However, stakeholder interviews highlighted one key difference between Aurora and WestWyck. In the former case, problems were prolonged and tended to be dealt with by notifying and seeking assistance from stakeholder organisations. In a number of instances, residents also had difficulty identifying and notifying the responsible organisation (S10; S13; S16). At WestWyck, the technical problems were immediately by-passed by switching to mains services while the responsible organisation was notified, usually by the Body Corporate.

#### 4.4.2 Projected climate hazards

This section looks at the sorts of climate hazards that may test the resilience of the systems, which includes householders and communities.

If we accept broad assumptions around ongoing community demand for energy and water services, Aurora and WestWyck are likely to be affected by the same 'primary' (direct, physical) on-site and off-site impacts of climate change. Both developments rely on the same catchment water supplies and lie within a climatic region likely to experience higher peak and average temperatures, shifts to increased rainfall intensity, and lower rainfall overall (CSIRO and Bureau of Meteorology, 2007). Some variability between the sites may be experienced due to WestWyck's location within inner Melbourne suburbs (e.g. night-time temperatures during heatwaves may be higher) and Aurora's location further inland (e.g. average and peak temperatures may be higher and rainfall lower).

The primary on-site climate related impacts at both sites are likely to be caused by drought and heatwaves. Off-site impacts are most likely to be caused by drought and secondary climate change impacts - blackouts and catchment fires.

**Drought:** Based on stakeholder interviews, on-site impacts of drought have been relatively limited and included reductions in on-site rainwater collection (at WestWyck) and increasing demand for water for irrigation (at both sites) (S1; S2; S3; S4; S14). While the recent drought and subsequent water restrictions last decade had no impact on recycled water system functions at either site, more severe or prolonged droughts could potentially affect all water system functions by forcing a major rationing of potable water supply <sup>2</sup>.

**Heatwaves:** Periods of high temperature were reported to affect the provision of hot water services (causing hot water systems to fail or leak at Aurora) and, according to some interviewed householders, reduced comfort in certain parts of homes at both developments (A1; A5; A6; A11; A13; W2; W6). While the hot water system faults can be resolved directly, increased heatwave frequency poses a potential problem for residents reliant on passive thermal design elements to maintain desired comfort levels.

**Blackouts:** As identified by interviewed residents and institutional stakeholders at both developments, off-site blackouts pose a temporary threat (in the order of hours to 1-2 days no more than once or twice a year) to system functions reliant on electricity. These include all non-potable water supplies, pumping and treatment functions. Blackouts pose a particular challenge to system functions because they often occur without notice. Blackouts pose no risk to gravity-fed rainwater (at WestWyck) and pressurised (mains) potable water supplies.

**Bushfires:** Fires pose no direct on-site risk to either development. However, upstream, they can contaminate Melbourne's forested water catchments (Lane et al., 2008, Wilkinson et al., 2007), and smoke can trigger distribution lines to shut down posing indirect risks to the security of mains water and electricity supplies. The risks posed by fires to both developments depend on a range of factors including their intensity and timing, which catchments are affected, the use of fire retardants, whether water supplies are already low, and capacity for treatment. Availability of water from desalination might also play a role in reducing supply disruption impacts from fire-related water contamination.

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<sup>2</sup> The impact of drought on Melbourne communities connected to the mains water will also depend on the availability of water from the Wonthaggi desalination plant.

### 4.4.3 Overview of potential impacts to services

The preceding subsections indicate that energy and water systems at Aurora and WestWyck face multiple risks and hazards. Although none of the risks are critical, they have the potential to affect energy and water related functions that residents currently expect and rely upon. For example, if recycled water systems do not function, or passive design features are insufficient to provide expected comfort levels, then these systems may be regarded as failing. In all systems, including distributed systems, user 'needs' and expectations tend to change and adapt with the system. A household that has been accustomed to tank water is likely to be more adaptive in water using practices, varying demand to meet supply. Hence, demand in this case is not a 'given' and 'needs' are relative and shifting. Moreover, there are also inherent risks associated with current grid-connected/ centralised systems, where such relationships between supply and demand in times of water scarcity can be expected to be different. The assessment of energy and water systems at the two case study sites against a range of current 'needs' for related services reveals the following three key issues:

- 1. Service needs or functions that are reliant on potable water or rainwater (drinking, food preparation and hygiene) are susceptible to a significant range of identified hazards.** As currently provided, these functions all rely on off-site processes and structures including water supply catchments, mains distribution networks and water treatment facilities. As a result they are susceptible to a wide range of off-site as well as on-site hazards.
- 2. Blackouts due to system failure or peak load and prolonged drought affecting water reserves both have the potential to significantly impact existing service needs.** In both cases, sudden and catastrophic system failure would have major consequences and so backup and / or information systems are required to allow users to understand system constraints and to adapt and prioritise service functions accordingly.
- 3. How technologies are configured and experienced can significantly shape notions of needs, risks and hazards.** For example, current system configurations at both sites involve flushing toilets ensuring that removal of human waste is vulnerable to water scarcity or pump failures. An alternative configuration, such as composting toilets would perform the same function without a vulnerability to changing water supply or technical conditions. However, widespread use of such technologies depends upon a coming together of cultural practices, perceptions of human waste services and technology availability. As introduced above, 'needs' and notions of risks and hazards are culturally constituted and constantly changing and therefore the prediction of future potential impacts to system services is problematic without a detailed understanding of these changing needs.

## 5. Analysis of system resilience and adaptive capacity

Energy and water systems face a similar range of hazards across Melbourne, with local variants. So far, the alternative systems at both case study sites have proven effective at providing the same types of services expected in conventional housing developments, with some additional services and benefits. Each site faces slightly different hazards, involves different system configurations, and contains a range of unique contextual factors.

In the absence of a well-tested process for quantifying and comparing socio-technical system resilience, this project sought to identify and characterise existing factors that could enable such systems to:

- A. Withstand, absorb and adjust to internal and external disturbance, and
- B. Engender flexibility in order to reduce the impact of disturbances.

Following the framework outlined in Section 3.3, these enablers of resilience and adaptation were derived from literature review together with analysis of each system's technical and physical design, institutional structures and functions, and associated social practices as presented in the following sections.

### 5.1 Technical enablers of resilience

The energy and water systems in the case studies display a number of technical and physical design features that contribute to (or enable) system resilience. These features (see Tables 2 and 3) help absorb, adjust to, or avoid impacts from system faults or external disturbances; many were incorporated at the system design stage. These features support system resilience by providing one or more of the following five characteristics:

1. **Functional diversity and redundancy** – allowing key functions to be performed through alternate means and / or alternate processes.
2. **Resource diversity and redundancy** – allowing resources to be replaced, either through back-up supplies of the same kind or through a different form of resource.
3. **Fail-safe mechanism** – ensuring impacts of faults are minimised or contained.
4. **Design for modification** – reducing barriers for changes to system behaviour or configuration.
5. **Feedback mechanism** – ensuring changes in system function (or contextual operating conditions) are detected and acted on rapidly.

**Table 2: Key technical enablers of resilience identified at Aurora\***

Desired system service or function	Example of system feature that enables resilience	Category of enabler
<b>Treatment of black-water</b>	Black-water can be pumped to mains sewer if required	Functional diversity
	Evapotranspiration bed can overflow to sewer if required	Fail-safe mechanism
<b>Grey-water treatment</b>	Real-time monitoring of grey water quality Telemetry controlled grey water bypass switch On-site manual switch (accessible by residents)	Feedback mechanism (between function and controller)
	Grey water system can overflow to sewer	Functional diversity
<b>Provision of water for household (non-potable) use</b>	Multiple water sources (grey water and back-up mains water)	Fail-safe mechanism
	Mains water back-up is pressured and does not rely on pumps	Resource diversity
<b>Hot water supply</b>	Multiple water sources (rainwater and back-up mains water)	Functional diversity
	Mains water back-up is pressured and does not rely on pumps	Resource diversity
	Capacity for solar and gas water heating	Functional diversity
<b>Provision of water for external (non-potable) use</b>	Multiple water sources (rainwater, grey water and mains water)	Functional diversity
	Mains water back-up is pressured and does not rely on pumps	Resource diversity
<b>Stormwater collection and disposal</b>	Multiple stormwater collection and infiltration points including rain-gardens and sales	Functional diversity
	Excess stormwater can drain to mains stormwater network off-site	Functional diversity
<b>Building heating</b>	Hydronic heaters are driven by solar and gas	Fail-safe mechanism
		Functional diversity

\* Information in this table is based on site visits and stakeholder interviews

**Table 3: Key technical enablers of resilience identified at WestWyck\***

Desired system service or function	Example of system feature that enables resilience	Category of enabler
<b>Sewerage treatment</b>	Pumping station can be powered by generator if required (though not held on-site)	Functional diversity
	Partly treated waste-water can be pumped to Craigieburn WWTP to reduce demand on the Aurora WWTP	Functional redundancy
	In the event of a fault in the treatment system, the 1ML tank provides a temporary back-up supply	Functional redundancy
	Excess treated wastewater (at Class B) can be stored for extended periods in the on-site holding dam. If necessary, Class B water can be discharged to irrigate land dedicated for this purpose	Fail-safe mechanism
	Sewerage pumping station has overflow storage capable of holding a volume of sewerage equivalent to three hours peak flow	Fail-safe mechanism
	The plant has been designed to allow for an increase in treatment capacity if required	Design for modification
<b>Recycled water supply</b>	In the event of failure to deliver Class A water, mains reticulated water can be plumbed in to supply the third pipe delivery systems.	Functional diversity
	In future, Class A water will be pumped to a holding tank on nearby hills that will be able to provide gravity fed recycled water to Aurora (planned but not yet in operation)	Functional diversity
	The class B holding dam provides additional back-up water supplies (as input to the recycled water treatment system) during periods when demand for Class-A water exceeds inflow of wastewater	Resource redundancy
	In-line water quality monitoring systems are designed to detect and prevent delivery of sub-standard Class A water to the 1ML holding tank	Feedback mechanism Fail-safe mechanism
<b>Hot water supply</b>	Capacity for solar and gas water heating	Functional diversity
<b>Stormwater collection and disposal</b>	Multiple stormwater collection and infiltration points including rain-gardens, swales and retention basins	Functional redundancy and diversity
	Overflow drainage area	Fail-safe mechanism

\* Information in this table is based on site visits and stakeholder interviews



**Functional diversity:** Examples at both sites include the ability to heat water using gas or solar energy and the capacity to switch from community scale wastewater treatment to mains treatment. Plans to gravity feed recycled water to residents from a hill-top reservoir at Aurora will also diversify the way water is supplied to residents, ensuring that supplies will be unaffected by temporary blackouts or pump failures. At WestWyck, the capacity to switch from on-site grey and rainwater collection and water pumping to pressurised mains water to fill tanks and hot water systems demonstrates three areas where functions (water collection, distribution and storage) can be provided in multiple ways if a problem occurs. As described by one stakeholder:

*"[When something goes wrong] the first thing we usually do is go into a controlled management phase and say 'ok, we've got a problem so let's divert the system so that it's not gonna cause grief...' So we bypass it – go back to conventional technology... just go to the bypass, just turn the tap, so now they've got water from the mains rather than water from the [on-site] system." (S3)*

**Resource diversity:** The provision of both potable and non-potable water to both developments is significant from a resource diversity perspective. At the time of this assessment, the quantity of recycled water exceeded demand at Aurora but this is expected to change as additional settlements are connected to the recycled water grid. At WestWyck, demand for alternative water sources exceeds supplies but the diversity of sources (rainwater, mains supply and recycled grey water) is greater than at Aurora. The advantage of this configuration is reduced reliance on any single source.

By diversifying water supplies, the systems at both developments reduce demand on mains reticulated supply. Although the volume of mains water saved is a very small proportion of overall mains supply, both system models indirectly augment mains storage capacity (a form of redundancy). Improved system resilience at Aurora also stems from the capacity to store partly treated (Class B) water and fully treated (Class A) recycled water as a back-up when demand exceeds supply.

**Fail-safe mechanisms:** Various fail-safe mechanisms are used as part of the water systems at both developments. Examples include passive overflow functions built into sewerage systems at both sites, which prevent uncontrolled discharge in the event of excess supply (e.g. caused by stormwater infiltration). As a member of the WestWyck Owners Corporation describes:

*"Ultimately what we're relying on is diversion systems, so that if our local Green systems were to fail then we can plug in to the major infrastructure that's there, like if our black water system fails we can divert to sewer, if our grey water system fails we divert to mains water." (S3)*

**Design for modification:** The Aurora wastewater system has been designed to allow expansion of treatment capacity as demand increases. This type of modification does not affect the core structure or functions of the system (S7).

**Feedback mechanism:** Water systems at both developments include a range of fault detection and alert technologies that provide system managers and also users (in the case of WestWyck) with real-time information on the performance of water treatment processes. At WestWyck manual switching between water supplies is currently required in response to a malfunction in water treatment but will soon be converted to a remote (telemetry-controlled) switch. Additional mechanisms such as emails and a paging system are also used to assist in the feedback of information between WestWyck residents and WOC. (Anon, 2011)

## 5.2 Institutional governance and management enablers

Formal governance arrangements as well as informal relationships between stakeholders support on-going system functions. Many governance and management enablers were not created specifically to support system resilience but have evolved with the systems. In some cases their role in system resilience has become evident only after faults or disturbances occur. For this reason, institutional and governance enablers of resilience and adaptation are more difficult to identify than technical enablers. The institutional and governance arrangements that played a role in supporting system resilience can be categorised in five areas:

1. **Cross-scale learning and information exchange** – allowing knowledge gained by stakeholders at one level of system function to be passed to stakeholders at another;
2. **Clear lines of responsibility** – ensuring the scope of stakeholder responsibility for system governance is clear and understood by all stakeholders;
3. **Cross-scale influence** – allowing stakeholders existing at one scale to directly influence those operating at another;
4. **Feedback mechanisms** – ensuring faults are detected early and affect a rapid response; and
5. **Embedded learning and experience** – ensuring stakeholders responsible for system functions have the depth of knowledge about system operation to understand and manage its vulnerabilities and have the capacity to respond to novel shocks.

**Cross-scale learning and information exchange:** The level of learning and exchange of information between system stakeholders was positively correlated to on-going system function and the capacity of systems to respond positively to system shocks. At **WestWyck**, stakeholders saw learning about system function as an on-going process, linked to a constant improvement of the systems operating on-site in a process that everyone could contribute to. As one stakeholder noted:

*"[System adjustments are] a bit related to the innovative nature of the technology... these guys [the service contractors] are learning as they go and I think WestWyck provides them a laboratory in a sense. 'Yes we've installed a system for you but we're working out the best ways to make this system work'." (S3)*

Thus, the process of learning and system adjustment at WestWyck was seen as contributing improvements in long term system resilience:

*"The next installation they [the contractors] do somewhere else will probably be a little bit better, bit more efficient, a bit more robust... than the one we've got. But over time we'd expect many of those technological developments to be incorporated into our system. So it gets upgraded as the guys perfect the technology." (S3)*

The process of learning about the energy and water systems was commonly seen as something the developers, residents, contractors and the Owners Corporation management could all assist with. Community cohesion and information sharing amongst all stakeholders was therefore highly valued.

At **Aurora**, learning and information exchange within the community and between the community and other organisations was less evident. The formation of the Aurora Community Association (ACA) was seen as a significant development by some, but by others it was viewed with shortcomings:

*"...the association works well for people who are prepared to be part of their community and to interact ... but ... there are a lot of people who are really disengaged..." (S16)*

*"it comes down to people paying off mortgages and spending a lot of time at work ... and not feeling like they have a lot of energy and stuff left over at the end of the day... which is hard in these kinds of places [suburbs]." (S16)*

**Cross-scale influence:** The capacity for system stakeholders to influence each other also plays a key role in determining how problems are dealt with. Places Victoria's support for the formation of a residents' association is one example where cross-scale interactions have facilitated a positive outcome for some in terms of system resilience:

*"VicUrban [Places Victoria] were keen for us to set up a residents association because they wanted the community to be sustainable and to be able to look after itself once they were gone and so they're kind of thinking ahead for the long term... [about] some systems and grass roots community organisations so that ... there's longevity and creating a resilience and connected community... I really take my hat off to VicUrban [Places Victoria] for the work that they did with the community..." (S16)*

The association was set up in 2009 and is seen as a more effective agent for raising concerns to service providers than individuals:

*"...it was set up as a way for residents to have a voice and be able to have a say in what was going on in the estate and be able to have ... more clout in dealing with organisations and with government departments and agencies ..." (S16)*

It was successful in negotiating on behalf of residents to improve services from the site's internet provider, but there is a perception that it faces limitations in operation:

*"...our biggest stumbling block at the moment is getting new people on board to start to take on responsibilities [who] are willing and able to do that..." (S16)*

At **WestWyck**, critical services are provided on-site. Management and maintenance of those services is conducted through the WestWyck Owners' Corporation (WOC). The WOC institutionalises the ability for individual households to influence governance of the site overall (at one scale) and also acts with the legal authority to represent households when dealing with other organisations (at another scale). Because system faults affecting residents have occurred on-site (with the exception of blackouts and potable water shortages), WOC has been able to act effectively on behalf of residents to address problems.

**Clear lines of responsibility:** Knowing who is responsible for system governance, operation and maintenance was a key factor in determining system resilience and the efficacy with which system faults were addressed. As articulated by one respondent, a sense of responsibility is important:

*"...to have influence can be different, very different to when you see people who're actually in some level responsible for things... I find if they are responsible [as] opposed to thinking that they can have influence ... people seem to be a lot more resilient." (S10)*

At Aurora, many stakeholders expressed different opinions of where responsibility lay and how responsibilities changing over time are affected by initial contractual arrangements. As one respondent noted:

*"the infrastructure's [typically] planned and agreed upon through the developer contributions, so the project is then budgeted on those developer contributions so sometimes there can be a difficulty around changing or responding to things...the difficulty is that its agreed with such a huge project over a long period of time ...and then things change, needs change, demands change, the type of community that develops is different, so it can be difficult to find flexibility within it..." (S10)*

Where knowledge and understanding of responsibilities are limited, this increases residents' vulnerability and reduces their capacity to cope with system failures and disturbances. It increases transaction costs for information exchange and delays response times when problems occur.

"[the level of] empowerment and disempowerment is really, really important [to getting problems solved]. Unless responsibility is clearly defined, people often don't take it on to do things."

"In a WestWyck, there'll be a very high level of shared responsibility. So, if somebody sees something that really needs to be nipped in the bud straight away, they're likely as not to either get on and do it in a physical way or get onto it, in getting the right person to know that it needs to happen."

*"When you move to the next level, like Aurora... sometimes community wants to do something but often it feels disempowered. Like: 'that swale outside my place, that silt needs to be stopped, ... what do I do, is that my responsibility, or do I ring up the council, but when I ring up the council, they seems to be awfully slow in responding', or ... they don't see it as being an important issue in the scale of all the other things." (S15)*

At WestWyck, the clarification of responsibilities was assisted and formalised through the creation of the WOC. As one respondent noted:

*"Here is a community... who to varying degrees share things. Sharing things mean they've got collective responsibility. That means decisions about the administration of those systems needs to take account of some sort of decision making process and... formality to that." (S3)*

However, while responsibility is clearly defined at WestWyck, it is shared and not rigidly enforced. Residents, the developers and the Owners Corporation can all take action to address a system fault, but will ensure that the other stakeholders are informed:

*"At WestWyck, you've got a community there, that is well educated in the sense of collective responsibility; obligations to consider other people: 'we're in this together' ... they all know they're reliant on each other doing the right thing." (S3)*

**Feedback mechanism:** A distinct difference between the systems at WestWyck and Aurora was the different relative capacity for problems to be easily detected and acted on. At Aurora, a lack of community cohesion, clear lines of responsibility and effective links between residents and the institutions they rely on for their services means that when problems occurred and were detected, the path for information to reach the responsible organisations was slow, needed to be re-routed or never occurred.

In contrast, at WestWyck, connections between residents and between residents and the WOC are effective and rapid:

*"[if there's a problem] they yell, and when you yell the people closest hear you first." (S3)*

In addition to phone calls, residents have access to decision-makers and each other through formal meetings, and group emails. Residents are also linked through an interactive internet portal where people can register issues, as a result:

*"Everyone is aware of any communication going on." (S3)*

**Embedded learning and experience:** While not easily identified, the history of experience and learning embedded within the water and development industry and individual stakeholders was expressed as a significant contributor to system resilience at both sites.

*For example, at Aurora, the water treatment system uses well-tested technologies and incorporates a long history of water management experience. The water utility's risk management experience was also a key factor in its ability to adapt and apply the HCCCP (Hazard analysis and critical control points) procedure (developed for food safety) to assess risks from recycled water services specifically for Aurora (S5).*

On a smaller scale, the WOC's decade long engagement with the water systems from conception to operation has also meant that the physical systems and the institutional arrangements that have built around them are capable of addressing disturbances as they arise. In the case of WestWyck, this is particularly evident from the experience that the community, developers and contractors have all gained in constantly adapting to small system faults.

At WestWyck, there is an explicit focus by the WOC to expand the existing knowledge base and reduce dependency on just a few key service providers. This perspective extends to a future when the developer and all initial contractors may not be present but services and system governance will be just as necessary.

*"[The WOC] gives them [residents] a reason and a mechanism to ... to deal with the issues that they're left with...and sustain them as a community when the developer goes." (S3)*

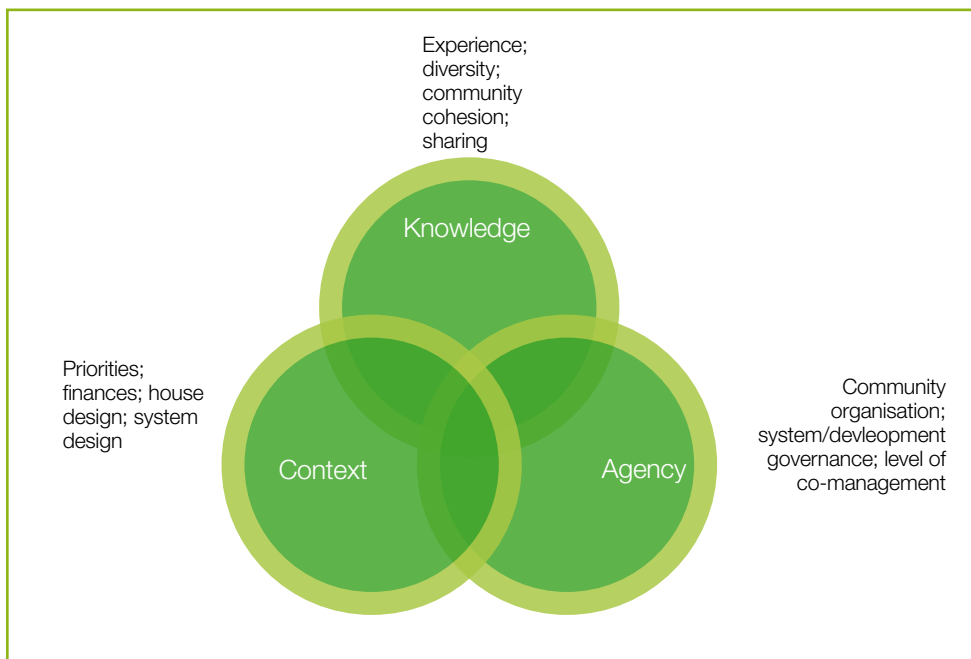
## 5.3 Social enablers

Households represent another key component in system functions that affect infrastructure resilience and adaptation to shocks and disturbance.

Analyses of the different arrangements at each location and the associated options, or lack thereof that they create for householders, have led to the identification of three factors, or social enablers, that are recognised as contributing to the underlying conditions influencing householders' practices and their capacity and confidence to deal with disturbance:

1. **Knowledge:** Provides individuals, householders and the community with the range of options they can draw on;
2. **Context:** Factors that shapes this knowledge so that the range of known options is further refined; and
3. **Agency:** The level of agency, influence or control householders have in dealing with issues and disturbances.

The social enablers associated within each of the three areas are neither mutually exclusive nor hierarchical, as Figure 6 illustrates. They are constantly interacting with and influencing each other, and changes in one might bring about changes in the other(s). This advises against any planning or interventionist approaches that might consider strategies focused on one or other element with the assumption that the desired outcome will naturally follow.



**Figure 6: Key social enablers of resilience**

### 5.3.1 Knowledge

Householder knowledge can be seen as the combination of current and past experiences, information derived informally through others (shared), and knowledge derived formally, through intentional communications (learned). Interview findings suggest that at both case study locations, householder knowledge is central to perceived and actual levels of risk and vulnerability, and therefore to resilience as a whole. Key enablers of knowledge identified are:

- Experience;
- Diversity;
- Community cohesion; and
- Knowledge sharing.

#### 5.3.1.1 Experience

Experience shapes perceptions of risk and vulnerability and directly informs both the range of options available for people to cope with disturbance and their personal level of tolerance to disturbance.

Residents at WestWyck and Aurora noted how previous experiences of service system faults helped them adapt behaviours in order to maintain core household functions during disturbances:

*"We spent some time in the Philippines, so we know how to flush water down [if the cistern does not fill]. So we just, you know, if it's yellow let it mellow kind of thing." (A9)*

*"[During power blackouts] we have got gas on the stove, so if we needed to have a cup of tea of anything we just used that and just candles and then went to bed." (A7)*

*"I lived in South Australia for a long time, and I was very conscious of water there, and I developed personal habits that made me very respectful of water." (W1)*

In effect, people's previous experience gave them a range of practical options to choose from that they felt some degree of familiarity with. Experience of previously altering their practices also increased their confidence in their ability to adapt, and find alternative solutions to future disturbances.



Many householders at Aurora noted that their knowledge/awareness of energy and water, and broader sustainability issues, had increased since moving to the development. There are many possible explanations for this, including the availability of recognisable technologies around the home, and the tendency for environmental narratives to become ‘normalised’ in the community (Newman and Dale, 2004). However, maladaptive technologies can also become normalised:

*“But when it’s the standard to use those things I guess you don’t even think outside the square, you think I’ve got the dryer I’ll just put them in the dryer.” (A3)*

Developers and builders may further entrench the ‘normalisation’ of such practices by making them part of the house package:

*“The site supervisor was kind enough to let our air conditioning guy come in and pre-wire or pre-pipe it all, because we’ve got four units upstairs and one here.” (A5)*

*“It was part of the house and land package... with that particular builder, because not everybody has it, most people have the evaporative yeah.” (A6)*

### 5.3.1.2 Diversity

In terms of resilience, diversity is generally regarded as a good thing. The greater the range of experiences that exists in the community, the greater the corresponding range of response options available to be shared. This research found that practices which align with associated technical and institutional arrangements, and incentives for increased resilience, tend to persist.

*“We’ll tend to recycle a lot more things now...we didn’t realise certain things could be recycled and others not.” (A1)*

*“If you get exposed to something, you query it, see how good it is, see if it fits in with your ideas, maybe listen to someone else.” (W7)*

In WestWyck, the profile of interviewed householders in terms of age, household unit and cultural background suggests that a degree of homogeneity exists. In a community that primarily comprises householders with extensive knowledge, interest, skills and/or experience related specifically to sustainability, homogeneity is less of a challenge to resilience than it might otherwise be. At Aurora, interviewees included Australians (4) most of whom had been raised in the country where only tank water was available, so they grew accustomed to short showers and flushing using a bucket; and migrants (6) who variously refer to earlier periods in their lives where they learned to adapt to having no water or power for three hours every day, or not having appliances such as clothes dryers. The diversity that exists in the Aurora community is a valuable asset that could be leveraged in the event of disturbance. However, in order to benefit from diversity, a community needs to have mechanisms by which this knowledge can be shared; mechanisms that facilitate community cohesion.

### 5.3.1.3 Community cohesion and knowledge sharing

Community cohesion, defined as the “social ties and community commitments that bind people together” (ABS, 2002, Berger-Schmitt, 2000) can emerge naturally in a community and can also be facilitated, supported or enhanced through community organisations and activities (Berger-Schmitt, 2000, Holdsworth and Hartman, 2009). The significance of community cohesion for system resilience has been noted in the broader resilience literature (Adger et al., 2005, Cutter et al., 2008, Gilchrist, 2009), as Gilchrist explains:

*“It [a well-connected community] is a means of managing chaos, building resilience and devising innovative collective solutions to intractable problems” (Gilchrist, 2009)*

At WestWyck, described by one householder as an “instant neighbourhood”, community cohesion was an intrinsic, explicit aim of the development from the outset and, by householders’ own accounts, has been achieved:

*"We make decisions communally. Whether you are sharing a clothes line or whatever, the fact that you are sharing, you have to talk with one another, and negotiate." (W2)*

*"Initially and with the standard approach, they said oh... we'll have four to six people or something and then just an annual meeting, and very quickly that dropped off and it's every household at every meeting – you know there is no committee we are all members and everybody's invited to every meeting. There's a fair bit of red wine goes around on the night so you know, it's a social event really..." (W7)*

The value of this sharing is evident from the householder interviews where different residents are associated with certain types of knowledge and expertise, and their help is sought accordingly depending on whether the question or problem concerns the water system, solar panels, water tank, garden or other component. Knowledge sharing in the community has also led some householders to adopt or enhance other sustainable practices not directly related to their water and energy use - such as recycling, personal worm farms, and using non-toxic cleaning products.

*At Aurora, the "newness" of the community and the less well-developed community organisation, were noted by some households more than others:*

*"Probably because it's not an established suburb, you know, we don't have that sense of community yet, well we do, but you know we have to help grow it to that point." (A7)*

*"It's not much of a neighbourhood around here unfortunately. People tend to keep to themselves. We came from a street where everybody knew each other and we had street parties. I guess that's with any new development, there has to be people around who are willing to kind of put themselves out there and put a bit of extra time into creating something." (A9)*

However, for respondents involved in the Aurora Community Association, their reported range of options for dealing with problems is noticeably expanded:

*"We get to learn a lot from each other, and with the problems that I had with the guttering. I mean, it affected next door and it's affected a few of these houses, so we're able to sort of band together." (A13)*

They have gained a greater knowledge of who lives in the community and the associated skills and expertise that they can utilise in different situations. The ACA provides a forum for sharing knowledge within the community through organised activities, workshops and tours; there is also exposure to more formal learning through lectures, seminars and courses organised through Whittlesea Council and Places Victoria.

Over half of interviewed householders did not participate in the Association and several were not aware of it. Structural factors may be at play here. Most interviewees appear to be time-poor due to family commitments, work and travel needs. Basic services such as shopping, taking kids to school, visiting cafes, libraries etc. are not localised, leading to car-dependency.

In contrast, householders at WestWyck are at different stages in their lives, are less car dependent and have services located nearby. They are therefore less time-poor and more able and ready to participate in the Owners' Corporation (OC), which also serves a more central function in this small community with systems that require a level of co-management. An additional difference between WestWyck and Aurora, and perhaps a contributing factor in their different levels of community cohesion, is that the developers at WestWyck sought to embed community cohesion into its design and development from the start, while at Aurora, Places Victoria attempted to build it *after* developing the estate.



Key points from this section:

1. Shared and learned knowledge, along with personal experience are essential in building community resilience;
2. Community cohesion can facilitate knowledge sharing; and
3. Knowledge sharing is more effective when there is community diversity and bridging or linking capital.

Social capital, community cohesion and ‘placemaking’ are widely recognised as ongoing needs for new urban communities. Although beyond the scope of this study, the current literature and approaches to placemaking can provide rich insights to inform the development of flourishing and vibrant communities with in-built social resilience.

### 5.3.2 Context

The features of context that are important as potential enablers of resilience can also be called ‘response shapers’. Based on the interviews, significant shapers of household practices, response options, and potential enablers of resilience are:

- Priorities and finances
- House and system design

#### 5.3.2.1 Priorities and finances

Priorities and finances reflect householders’ practical living situations and further refine and guide their decisions within the range of available and known options.

Over half of the interviewees at Aurora are families with young and teenage children where one or both parents work. Certain practices are described with reference to constraints, most notably regarding the volume and timing of laundering which inform frequency, water temperature and use of dryers; heating and cooling for young children; differences in preferences and times around heating and cooling; and lack of time available for cooking and gardening (often linked to travel times to and from school, work, goods and services):

*“...as [child] gets older he obviously uses more, he’s more of a consumer as well. We kind of are not as conscious now because he takes up a lot of my time... [my husband] works long hours and it’s just me and [child] and sometimes you just don’t have the energy for everything that you want to do.” (A9)*

*“There is a lot more work for me to be here and manage my children, and get them to school and whatever. Whereas I had family over there that could pick them up from school and do all that sort of stuff. But I don’t have that here.” (A5)*

*“A few times when he’s fallen asleep on the couch we put the fan on for him.” (A3)*

One WestWyck householder further illustrates this point:

*“I am possibly more efficient than what used be when I had three kids at home and running a business and not giving as much thought perhaps to that, so yeah.” (W2)*

Several Aurora interviewees also mention time as the main reason they have not read the Aurora home manual, joined the ACA, participated in community events, or sought help or advice from neighbours, Places Victoria or other stakeholders. It appears from interviewees’ accounts that expectations of living in a master planned community are invariably high and inevitably unmet:

*"If I lived at Epping Station I would be very happy, but I have to drive to get to the station and, the idea that they were going to build a train line, doesn't look like it's going to happen". (A8)*

*"Café, school, childcare centre, all these things that were going to be done by now you know, or at least started by now." (A7)*

*"I came from Lalor and I really miss, like I was very close to the streets, local shopping and for you to get to a bit of local shopping there's nothing here. I don't know how young families are finding to get a loaf of bread or a bit of milk or anything. There's not even a convenience store here. You have to drive back into Epping." (A2)*

For some householders, money may also limit options:

*"Two weeks after the warranty ran out, the whole [solar hot water] system broke down and there was no hot water and they initially refused to fix it at no cost, but then I got to speak to someone else and they agreed that they would waive the fee."(A12)*

The increased importance of the knowledge sharing and support that comes from social cohesion for lower-income households and/or isolated communities with family priorities has been noted in studies of social resilience (Orthner et al., 2004, Pelling, 2003):

*"As a household's economic resources (savings etc.) and income declines, it becomes harder to expend time and resources on community level work or obligations". (Pelling, 2003)*

Some households at Aurora appear to neither have the resources that might increase their individual resilience, nor access to appropriate mechanisms for community cohesion.

Contrast this with WestWyck, where not only is there the capacity to share certain costs associated with systems across the whole community, but there is also a sense of greater financial freedom for some householders which provides them with more options in responding to disturbance. For example, going to a hotel when it is too hot, working from another office if it is too hot/cold, or spending winters at a second home to avoid the cold. It is perhaps through having options such as these that some householders at WestWyck are able to better tolerate extremes of heat/cold and avoid feeling the need for air-conditioning or additional heating.

Differences in priorities and finances between the interviewees at each case study location also suggest that there may be differences their attraction to, and willingness/capacity to interact with, different types of energy and water systems. An acknowledgment of the diversity of Victorian communities, in terms of lifestyles, priorities, background and capacity, should underpin the assessment of 'appropriate' resilient systems.

### 5.3.2.2 House and system design

The design of the homes at WestWyck and Aurora appears to contribute to a generally increased capacity for householders to tolerate extremes of heat/cold, as compared with their previous or other homes. As illustrated in section 5.3.2, interviewees at both locations observe that their homes tend to stay cool/retain warmth for longer and, provided householders have good practical knowledge regarding how to heat/cool their homes efficiently, features such as orientation, insulation, window size/location, air flow and material use, provide them with a range of passive heating/cooling options.

The designs of the systems themselves also provide householders with options in the event of faults or disturbance, although these options are less visible and require less participation from the householders. For example, the grey water systems at both sites are still connected to the mains, providing a back-up source of water for toilets and gardens should either system be interrupted (resource redundancy). The blackwater system at WestWyck has the option to be linked to the main sewerage treatment, again providing the same optional benefit to householders, should problems arise, through functional redundancy. Solar hot water systems at both locations are gas-boosted, providing the option to be less/more dependent on solar energy depending on availability, and access to hot water (though perhaps limited) if the gas system fails (resource redundancy).

*"For the grey water if something goes wrong with the system it switches to mains so I've never not been able to flush my toilet ever." (W4)*

*"We've got a gas boosted solar hot water system so that, especially in summer probably works quite a bit but in winter not." (A4)*

There are also certain design features of the systems and homes at both sites that limit the options available to householders to carry out certain practices and respond to disturbances, and can result in maladaptive outcomes. Both locations are dependent on the mains grid for their electricity (solar photovoltaics at WestWyck feed directly to the grid) which means householders have no other options for electric heating/cooling, lighting or cooking (though most homes use gas for cooking) should this fail. Even if independent systems were viable, the cost for most householders at Aurora is currently prohibitive, and there is insufficient north-facing roof space to service all households at WestWyck, although options other than mounting on roofs could be explored.

*"Solar [electricity]'s part of the grid, we haven't got batteries so if the grid's down the lights go out you're not – you're not running a separate system you're running in part of the grid with the panels feeding in." (W7)*

*"There's limited north-facing roof space on the school so I wasn't able to get in on that last round so potentially there might be space." (W4)*

*"One of our project plans is in the future to put in a solar system...but yeah, can't really afford it at the moment so we're just going to have to wait a little bit longer."*

Both communities are also dependent on mains water to provide their potable supply. There are currently no accredited systems for providing potable water from tank or grey/black water at a community scale. However, access to tank and/or recycled water appears to be sufficient to prevent householders feeling vulnerable to a disturbance in mains supplies. Up to a certain point, they know what to do and feel they would be able to take steps in the future to increase their resilience:

*"Probably if we had a sort of climate change with the droughts, I'd really look at installing water tanks. Anything else apart from that, I probably wouldn't." (A10)*

*"But let's assume we are going to get another drought, which we will, those rain tanks might be adequate for a while, but they are not necessarily going to be sufficient for another extended drought." (W2)*

In terms of the homes, section 5.3.2 outlined ways in which open-plan designs, lack of venting and use of materials, combined with how the systems are installed, can present a number of challenges to householders' comfort. More direct implications of poor design in terms of climate-related disturbances have also been noted at Aurora:

*"When we had the heavy rains, we had water coming into the home and because we don't have eaves on our particular house and the water was coming in on a certain angle. There were a couple of joins from upstairs that, you know, weren't quite sealed." (A6)*

In identifying certain features of context that shape householders' options and responses to disturbance, this section highlights the potential outcomes of a lack of coordination between the role and activities of the house designer, the house builder, the system designer, and the system installer. The design and installation decisions these stakeholders make ultimately determine the lived experience of the householder. An absence of coordination and alignment of design and performance features between each of these elements increases the likelihood of unexpected and possibly maladaptive outcomes.

### 5.3.3 Agency

The level of agency, influence and control that householders have in dealing with issues and disturbances has emerged as a significant enabler of resilience. In this respect, the following two factors have been identified through this research as contributing to agency:

- Community organisation and system governance
- Co-management

#### 5.3.3.1 Community organisation and system governance

The significance of agency for the adaptive capacity and resilience of communities to climate-related and other disturbances, lies in the effect it has of closing the gap between system elements and increasing feedback and response times (Cox, 1998). Where householders and communities are more detached and isolated from the spheres of technical and institutional control, they may be less able to articulate or manage system issues. Agency bestows householders and communities with a level of control or a 'voice', which introduces a mechanism for feedback from the bottom-up as well as top-down and thereby increases overall system resilience (Tompkins and Adger, 2003).

*"In the context of climate change, many potential risks necessarily involve intervention and planning by the state, yet adaptation strategies are equally dependent on the ability of individuals and communities to act collectively in the face of risks" (Adger, 2003)*

The capacities to self-organise and act collectively appear to be essential pre-requisites of agency (Carpenter et al., 2001, Trosper, 2002, Adger, 2003). On the basis of these criteria, it is possible to assess the potential for effective agency at both Aurora and WestWyck.

At Aurora, institutional arrangements are characterised by a large number of stakeholders and a clear separation between the householder as the customer and receiver, and the developer, builders, contractors, utilities and local government as providers. Given this separation, it is unsurprising that there was a gap between householders expectations and outcomes, and attribution or responsibility towards providers rather than the community:

*"My perception was, okay VicUrban [Places Victoria] they show you all the recycled water and the conception of alternative systems but when you step out from there, you just going in the business way, luxuries. They definitely didn't differentiate. I don't know like maybe they did use it [environmental materials] but they didn't mention it. I think also the fact is, maybe they tried to keep the prices down in this area so they probably made assumptions about what people wanted to know." (A4)*

*"I think they [the builders] were more about quality and luxury [of additional fittings and fixtures] than the environment, the environment was not the main point." (A3)*

*"They weren't really pushing green or not pushing green: the choice you had was, you could have the normal lights or you could have the down lights, and we didn't really like the standard lights that they were putting in so we just upgraded. And we upgraded the whole house pretty much with everything." (A5)*

*"They promised two schools and one grocery, one something. And it's late, already here four years, nothing. So, yeah." (A11)*

The Aurora Community Association (ACA) has the potential to address this gap. However, of the three interviewed householders that were actively involved in the ACA, only two indicated that they use it quite purposefully as a way of interacting with Places Victoria and having their voice heard. More generally, based on the interviews, responsibility is not always clear as far as some of the residents of Aurora are concerned:

*Q: "Are you clear of the boundaries of responsibility between the systems you have?"*

*"No, I have no idea now." (A6)*

*"They [Places Victoria] couldn't fix [the solar system], there was nothing that they could do. They weren't in charge of the maintenance because we were still under warranty with [builder], so then we had to get [the builder] to come out. In the first instance they thought maybe it was an installation issue so they sent out the installers." (A5)*

*Q: 'But it was an appliance issue...?'*

*"Yeah." (A5)*

Moreover, residents in communities with limited local organisational capacity often have no idea if other residents are experiencing the same problems and so root causes and solutions, if they exist, are rarely identified. On several occasions at Aurora, the interview was the first time that residents heard of other households raising similar issues. This situation increases households' vulnerability to system disturbance because it:

- Decreases their capacity to share knowledge with other householders;
- Does not reinforce collective responsibility;
- Limits opportunities to identify issues across the community; and
- Places a burden on individual householders' time and finances in having to individually bear the costs of any action.

As Woolcock and Narayan (2000) state, "The very capacity of social groups to act in their collective interest depends on the quality of the formal institutions under which they reside."

WestWyck, in contrast, was conceived of as a self-organised community from the start. The developer is also a member of the Owners' Corporation and all contracts and negotiations with system manufacturers, installers and contractors are enacted through the WOC:

*"The approach to the different providers are done through the body corporate." (W2)*

Lines of responsibility are clear and householders appear confident in their knowledge of who to contact/ what to do in the event of a problem. The boundaries between the technical systems, institutions and 'customers' are much less distinct than at Aurora, and the technical systems, or more accurately the institutional structures surrounding them, actually rely to some extent on interaction and feedback from householders to note any changes in performance. This is facilitated firstly by sensory feedback from system hardware (the sound of a pump, or its absence; the water quality warning alarm; the depth of water in the worm tank or reed beds), and secondly the opportunity to interact with the community and address problems using existing and shared knowledge.

*"I only noticed it in here because the pump wasn't working. It's quite a loud, quite a loud pump." (W3)*

*"So incrementally, just to save emergencies and so on we've gradually found out which button we need to press. The first time that happened I mean there were six of us over a whole weekend with this alarm going and nobody knew where to begin, you know we all just sort of looked at one another and left it. So I think knowledge is power and then recognising that there are some things that you have to call for assistance." (W7)*

For significant issues, householders use the OC so that the nature and extent of the problem, and its implications for the whole community can be assessed. Decisions tend to be arrived at collectively and the implications, in terms of cost or otherwise, shared appropriately. This level of agency:

- Increases householders' capacity to share knowledge with other householders;
- Creates clarity around who is responsible:
- Allows opportunities to identify issues across the community
- Provides the means for a collective and 'louder' voice to act on behalf of a larger group and activate/enable timely response; and
- Reduces the burden on individual householders' time and finances in having to individually bear the costs of any action.

The capacities to self-organise and act collectively may be largely dependent on the community, however, the institutions involved must be prepared to interact, listen and receive this 'action' to create a situation where "synergistic social capital and inclusive decision-making institutions promote the sustainability and legitimacy of any adaptation strategy" (Adger, 2003; (Smith and Stirling, 2008).

### 5.3.3.2 Co-management

Co-management refers to "*collective control and responsibility for the management of resources*" (Strengers, 2011) and is an institutional arrangement said to "*promote[s] the adaptive capacity of societies to cope with climate change*" (Adger, 2003).

Research has shown not only that reconfiguring systems to require mutual control and responsibility is more likely to engage householders in less resource-intensive practices, but also that this approach can potentially change the underlying conditions by which resource provision and consumption take place (Strengers, 2011). In this paper, Strengers highlights the potential for this paradigm shift towards the 'co-management of everyday practices' to become an enabler of technical and institutional, as well as social resilience.

WestWyck is an example where co-management of the systems of provision provides householders with greater agency over their operation and maintenance than has been demonstrated by more typical development provision models. Beyond WestWyck, it is possible to envisage systems within which existing practices are reconfigured. In such a system:

*"[The] relationship of co-management dominates, whereby carriers and facilitators of everyday practices are mutually and collectively responsible for their composition and enactment in everyday life. Flexible and interchangeable roles emerge across multiple scales. Householders and communities co-manage practices within the context of the household, through their interactions with others, and with reference to their relationship with utilities, government and materials infrastructures".* (Strengers, 2011)

A proponent of co-management as a way of expanding the possibilities for adapting to climate change, Adger (2003) suggests that "*building successful collective actions, possibly in the form of co-management arrangements for natural resources can enhance the resilience of communities, as can maintaining ecosystem services and ecosystem resilience.*"

This section has shown that social enablers of resilience are inextricably linked with the design and implementation of the technical infrastructure and the institutional arrangements surrounding it. The three elements cannot be separated if maladaptive responses to alternative systems, designed to improve resilience to climate changes and other disturbances, are to be avoided.



## 5.4 Implications for supporting resilient infrastructure

The analysis has identified a diverse set of technical, social and institutional enablers that act collectively to support system resilience. While the overarching implication is that more resilient infrastructure systems would incorporate multiple enablers from each of the three domains, system designers, investors and manager decision-makers face professional, financial and logistical constraints that limit how system resilience is prioritised. Reflecting this challenge, the following two sub-sections highlight the key issues affecting the replicability of WestWyck and Aurora (and community-scale systems more broadly), and suggest a way to prioritise the types of resilience enablers more likely to prove valuable, under contextual uncertainty.

### 5.4.1 Replicability

From a technical perspective, there are no significant barriers to replicating the energy and water systems used at WestWyck and Aurora. Developers considering either option today, face few of the same technical barriers encountered when the systems were originally designed and built. When initial concept designs for the water treatment system were taken to market, as one WestWyck stakeholder mentioned *“finding a good contractor was really difficult.”* but this situation changed rapidly as: *“...in that relatively short period of what, six years, suddenly the market had a whole lot of new options”.* (S1)

Similarly, systems like Aurora are now planned or in operation across Australia (e.g. Gracetown WA, Pimpama Coomera QLD, Eynsbury and Sandhurst VIC). In many respects the leadership of the local water utility in supporting and changing its internal culture (and even some aspects of its structure and billing system) to accommodate Aurora (and to a lesser extent WestWyck) has assisted the propagation of water service systems (Anon 2010). In practice, the technical feasibility of replicating the types of water systems used at either development will depend more on suitable contextual conditions such as suitable site geography, the development population and available space; rather than the maturity of the technologies involved.

From a regulatory perspective, the only technical system that may not readily be replicated given the Victorian regulatory regime is WestWyck's blackwater system. As currently defined, Victorian recycled water standards do not pose any direct barriers to replicating WestWyck's greywater or rainwater systems - provided systems supplying multiple dwellings are EPA compliant and meet the necessary water treatment quality and system management standards (EPA Victoria, 2003). However, direct challenges may arise depending on the level of awareness, risk aversion, council approval processes, and/or follow up and monitoring processes. Regarding the latter, as one stakeholder notes:

*“We believe there should be an overseeing committee or organisation for these sorts of systems”* (S1)

The financial feasibility of replicating the energy and water systems at both sites depends on context. The systems were not designed on a simple profit-based model. As one Aurora stakeholder puts it:

*“The premise we were looking at was that people are going to be paying a premium because there's been a significant additional cost for innovation in order to recover that you needed to be able to offer people something that other people didn't have and that was green lawns, green nature strips, green oval etc.”* (S4)

Indirect subsidies to traditional infrastructure and externalities associated with 'traditional' energy and water infrastructure operation poses a significant 'hidden' impediment to system replication and further innovation in community-scale infrastructure. WestWyck and Aurora were designed with the specific intent to demonstrate a form of urban development that required a lower environmental impact than conventional alternatives. The choice of energy and water systems employed reflects these values. Positive externalities arising from system designs used at both developments include:



- Reduced pollution loads to water ways;
- Lower discharge rates to storm and sewerage mains;
- A lower carbon footprint;
- Increased urban amenity;
- Reduced demand for potable water and electricity (which helps to delay mains infrastructure capacity upgrades); and
- Lower community vulnerability to water shortages, drought, mains water contamination and supply faults.

Yet of these benefits, only WestWyck's ability to reduce its load on mains sewerage systems is recognised by the wider institutional structure in which it sits (in the form of lower service charges). In this operating context, where all impacts from provision infrastructure are unaccounted and service costs do not reflect a greater range of costs and benefits inherent within them, future innovation in infrastructure design and adoption has no incentive to pursue models that offer lower impact, higher public goods and are more adaptive to climate change related disturbances.

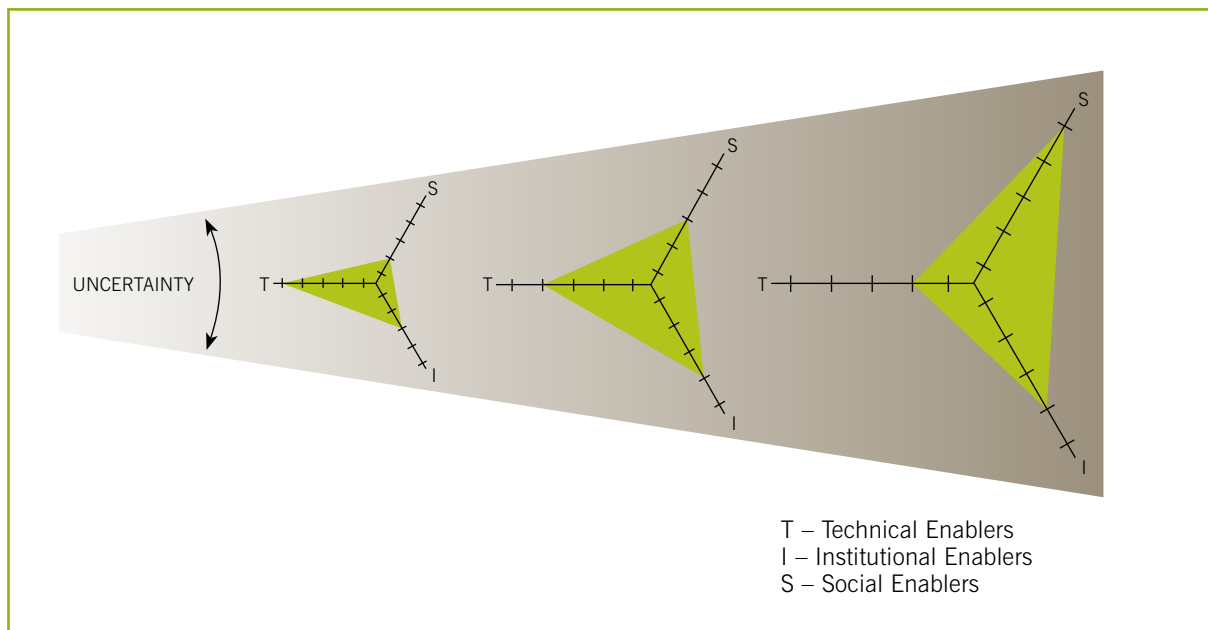
#### 5.4.2 Managing climate uncertainty

The uncertainty associated with potential climate change impacts poses a key challenge because the enablers identified through this research impart resilience in different ways and at different timescales. Comparatively, they also require very different approaches along the design-build-operate pathway. Infrastructure systems also have life expectancies ranging from decades to over a century and, in most situations, decision-makers will not know the full range of climate related impacts that will test infrastructure resilience. Inevitably, longer-term investments in provision systems face greater uncertainty. In this context, making system design decisions are unavoidably challenging.

As this project has indicated, technical, social and institutional enablers of resilience impart different qualities of resilience to infrastructure systems. Bearing in mind that this proposition requires further exploration, preliminary findings would suggest that:

- **Technical** enablers are better suited to conditions where a higher degree of certainty exists about short-term future risks. Despite their role in providing a guarantee against future uncertainty, technical system components that provide functional diversity or redundancy still rely on the assurance that environmental or institutional conditions do not change radically. They assume that the basic make-up of system structures and functions remain relevant and viable.
- **Institutional** enablers that impart resilience to infrastructure systems are likely to be particularly beneficial in conditions of greater uncertainty, over the medium to long-term. Characteristics such as the capacity for learning and cross-scale interaction can enable institutions to identify where systems are more or less vulnerable to emerging conditions and organise resources needed to adapt system design and functions to better reflect those conditions.
- **Social** enablers of resilience are likely to be more valuable under conditions of even greater uncertainty, again over the medium-longer term. In contexts where operating conditions are highly volatile or involve a high possibility of surprise, characteristics such as strong social capital and agency are likely to prove highly beneficial to systems, enabling them to adapt and evolve rapidly even when technical and institutional system components fail.

Figure 7 emphasises under which conditions the different types of enablers should be emphasised.



**Figure 7: Managing the trade-off between resilience enablers when designing for future operating conditions**

This is not to imply that technical enablers of resilience are of little value under conditions of high uncertainty or that social enablers are irrelevant in conditions of stability. Rather, it reflects that the resilience of any system is a dynamic state that fluctuates over time depending on internal and external conditions. The implication of this is that designing infrastructure (or any other system) to be resilient for a particular set of conditions means that it may be less resilient for another. Moreover, shifts toward greater uncertainty require a greater emphasis on enabling systems to change, which requires investment in social and institutional enablers of resilience.

## 6. Research outcomes

This pilot research has demonstrated that enabling resilience in new community developments in Victoria requires new techniques and approaches to achieve resilience in the context of socio-technical systems with complex interdependent qualities. As Adger (2003) states:

*“Adaptation processes involve the interdependence of agents through their relationships with each other, with the institutions in which they reside, and with the resource base on which they depend”.*

As a preliminary step towards these potential new techniques and approaches, this project provides three key outcomes:

1. A set of technical, institutional and social enablers of resilience;
2. Key findings regarding resilient energy and water systems for residential developments; and
3. Preliminary criteria for the assessment of resilient urban systems.

### 6.1 Enablers of resilience

The energy and water systems at Aurora and WestWyck exhibit multiple social, technical and institutional enablers that contribute to system resilience by helping to alleviate or avoid most of the key disturbances to system functions, such as drought, heatwave, blackouts and bushfire. The principal enablers of resilience identified through this process are summarised below.

**Table 4: Summary of enablers**

Technical Enablers
<ol style="list-style-type: none"> <li>1. Functional diversity and redundancy – allowing key functions to be performed through alternate means and / or alternate processes</li> <li>2. Resource diversity and redundancy – allowing resources to be replaced, either through back-up supplies of the same kind or through a different form of resource</li> <li>3. Fail-safe mechanism – ensuring impacts of faults are minimised or contained</li> <li>4. Design for modification – reducing barriers for changes to system behaviour or configuration</li> <li>5. Feedback mechanism – ensuring changes in system function (or contextual operating conditions) are detected and acted on rapidly.</li> </ol>
Institutional Enablers
<ol style="list-style-type: none"> <li>1. Cross-scale learning and information exchange – allowing knowledge gained by stakeholders at one level of system function to be passed through to stakeholders at another</li> <li>2. Clear lines of responsibility – ensuring the scope of stakeholder responsibility for system governance is clear and understood by all stakeholders</li> <li>3. Cross-scale influence – allowing stakeholders existing at one scale to directly influence those operating at another</li> <li>4. Feedback mechanisms – ensuring faults are detected early and affect a rapid response</li> <li>5. Embedded learning and experience – ensuring stakeholders responsible for system functions have the depth of knowledge about system operation to understand and manage its vulnerabilities and have the capacity to respond to novel shocks.</li> </ol>
Social Enablers
<ol style="list-style-type: none"> <li>1. Knowledge – Experience; Diversity; Community cohesion; knowledge sharing</li> <li>2. Context - Priorities and finances; House and system design</li> <li>3. Agency - Community organization; System governance; Level of co-management</li> </ol>

Resilience is not simply a function of interactions of enabling components or properties, but is a dynamic property at the socio-technical system level. A system's capacity for resilience is associated with a range of enablers that prevent the system from being immutable, fixed, incapable of change, path dependent, and 'brittle'. Depending on the nature of each enabler, and how they interact, they can equally become 'disablers' of social resilience, resulting in maladaptive as opposed to adaptive outcomes. For example:

**i)** Even if a system's infrastructure can be regarded as technically resilient, if a householder lacks personal experience of system disturbance or extreme conditions, and has limited exposure to other people who may have such experience, their access to alternative knowledge is limited and their available options reduced if they do experience disturbance or discomfort. If institutional enablers, such as direct links with the community, appropriate contracts and/or embedded learning are also lacking, this may lead the householder to adopt whatever is 'normalised' practice amongst their peers, which may or may not be maladaptive, for example, air conditioners are increasingly visible, commonly promoted by builders as a standard appliance and largely 'normalised' as an acceptable response to heat discomfort.

ii) If the system is reliant on one resource supply (i.e. no functional diversity), there are no other options if that technology should fail. In the absence of technological resilience, the hope is that other enablers would step in such as diverse and shared knowledge on different ways of performing the same function, and/or appropriate planning and lines of responsibility at the governance level to facilitate the emergence of a suitable and timely response. If these enablers are not active, the lack of functional diversity in the system becomes a significant risk for a maladaptive response.

iii) If there is no long-term management plan for the systems and the communities reliant on them, there are limited options available for effective adaptation in the event of a change in ownership, responsibility or community needs. Other enablers such as direct links with the community and embedded learning might then become critical factors in determining whether such changes lead to adaptation or maladaptation.

This highlights the importance of an integrated approach to building resilience across all timescales that incorporates the appropriate technical, institutional and social enablers at every stage of the development process for new developments.

## 6.2 Key findings

The key findings of this research, based on evidence of the technical, institutional and social arrangements surrounding two case study developments, and the identification of resilience enablers, are as follows.

**Finding 1: The resilience of community-scale infrastructure systems is a dynamic state that results from the interaction of diverse and context specific technical, institutional and social ‘enablers’.**

The resilience enablers identified at both sites perform a definable range of functions, some of which are more important than others.

Technical enablers, such as fail-safe mechanisms or redundant functional components tended to be dedicated specifically to providing resilience. Once installed, some could operate independently of people and managing institutions. The Aurora water system was designed with an emphasis on maximising the role of technical resilience enablers operating at the supply end. However, technical enablers alone are not enough. In most instances where faults were avoided or addressed, people and institutions played key roles in the identification, appraisal and development of adaptive responses. At WestWyck, where a significant adaptation in systems design occurred to increase resilience, changes were required in individual practices and responsibility, institutional arrangements and technical configuration. Institutional enablers, such as those providing clear lines of responsibility and the capacity to influence stakeholders, and social enablers, such as those providing learning and information exchange were critical in the detection, response and on-going adaptation to system faults and hazards.

**Finding 2: Climate change poses few direct short-term threats to the local energy and water systems examined. However, both developments also depend on larger energy grid and reticulated water systems subject to indirect threats from climate change.**

The urban and peri-urban location and connection to centralised supply networks ensure that most impacts are buffered. Blackouts and extended droughts are the most significant hazards. Clearly, these exposures are site specific and our two pilot cases are not sufficient to draw wide conclusions about the function of energy and water systems—indeed, it is reasonable to assume that in some cases climate change does provide direct threats to these systems. Moreover, while we have not conducted a study of potential costs of energy and water services under climate change, there are implications associated with the costs of maintaining systems and potential increased demand for services. Here, we focus upon the technical efficacy of such systems.

Blackouts are a tertiary impact from climate change that has the capacity to temporarily affect almost all water services at WestWyck (due to their reliance on electric pumps) except the supply of gravity fed rainwater and pressurised mains potable water. Supply of recycled water to Aurora is also vulnerable. In practice, the impact from blackouts is minimal due to their temporary nature (a period of hours to days) but could pose a greater problem depending on the extent to which the frequency and duration of blackouts is affected in future.

Extended drought is a more serious threat because of its ability to affect mains water supplies, which underpin all of Aurora's water services and potable services at WestWyck. However, Aurora and WestWyck residents are better placed to handle drought and water rationing relative to other Melbournians as the systems in place maximise the utility of water multiple times through re-use and recycling. Residents at both sites were unaffected by water rationing in the latter years of last decade.

**Finding 3: Climate adapted infrastructure requires integration of technical, institutional and social resilience. Where uncertainty exists regarding future operating conditions, institutional, and social enablers may prove to be particularly important enablers of resilience.**

Under operating conditions of high certainty, a priority emphasis on incorporating technical enablers within system designs may prove an adequate approach to ensuring infrastructure resilience. However, where uncertainty over the type, intensity and frequency of future hazards is high, system designs will likely benefit from a greater emphasis on institutional enablers to ensure infrastructure resilience. Conditions of extreme uncertainty would require systems to be designed in a way that resilience depends less on technical enablers and more on the strength of social enablers.

**Finding 4: An emphasis on technical resilience in the design of novel infrastructure systems at the expense of community and institutional enablers of resilience may place certain communities at risk from climate change and other disturbances. This risk is likely to be greatest in residential developments where social capital is weak, and where system designers and investors have limited on-going responsibility for system functions.**

Where technical arrangements take precedence and assumptions are made about the functions, users and services of systems, then urban developments may lack the social and institutional capital required to support urban resilience. This may be exacerbated in cases where communities are deficient in other forms of capital such as time and financial resources that can assist in the development of social capital and underpin adaptive capacity when system faults occur or the reconfiguration of a system is required.

**Finding 5: Victoria's current regulatory landscape poses few direct barriers to the replication of the systems examined, but it does restrict innovation in community-scale infrastructure systems.**

With the exception of small scale on-site blackwater treatment at WestWyck, the energy and water systems at both developments face no direct regulatory barriers to replication. However, current design of regulations (including the design of energy and water service pricing) does not adequately account for either the positive or negative externalities associated with traditional or alternative energy and water services. This situation represents an uneven operating environment that disadvantages more innovative energy and water systems that provide public goods, including such as lower carbon footprint to conventional services; lower nutrient loads to waterways; and reduced or delayed demand on centralised infrastructure. Developments that internalise externalities or reduce environmental loads (such as Aurora and WestWyck) are therefore at a relative disadvantage and this disadvantage can be expected to act systemically against the development of community scale systems and realisation of the benefits they accrue.

**Finding 6: Community scale systems potentially provide both advantages and limitations over conventional centralised systems. Integrating centralised and distributed system models may maximise advantages and minimise limitations associated with both models. An integrated system comprising linked provision infrastructure at multiple scales may offer the best way to build resilience at all levels - from resource producer to resource user.**

The examined case studies indicate that combining distributed and centralised models can deliver accumulative benefits by:

- **Reducing demand on centralised supply resources and distribution infrastructure**—utilisation of distributed resources, including the re-use and recycling of those resources reduces demand on centralised supplies. These changes can accrue to utilities as a delay in the need for investments in infrastructure capacity upgrades.
- **Increasing adaptive capacity at the demand-end of supply systems**—benefits include the flexibility to disconnect from centralised supply to avoid impacts spreading through the network (e.g. as a result of contamination or rolling-blackouts); re-time or adjust particular activities (e.g. rationing); shift between resources (eg. greywater to rainwater), or triage less important services (e.g. car washing for garden watering). Here, specific adaptations are not as important as the willingness, capacity and familiarity with doing so. Community-scale infrastructure may increase people's capacity to co-manage their consumption practices.
- **Increasing feedback between smaller and large-scale systems**—community-level institutions can play a critical intermediary role between end-users and centralised service providers by leveraging collective concern, financial resources and learning.
- **Driving technical, social and institutional innovation**—the examined case studies have demonstrated considerable innovation at the site level through resource efficiency, and site and infrastructure design. They have also had a positive impact on sustainability-related innovation in the water sector and residential development industry.

## 6.3 Preliminary assessment criteria

Preceding sections have drawn on the analyses of research data to identify enablers of resilience that are considered critical, by their presence or absence, to householders' capacity to absorb or adapt to disturbances in their water and/or energy systems. Drawing upon the enablers, and the above findings, the following preliminary assessment criteria for building/ assessing/ managing resilient urban systems are presented:

### Criteria 1

Resilience is acknowledged as a dynamic and not an end state. Appropriate measures to recognise and respond to changes over time have been accounted for in long-term monitoring, managing and maintenance strategies across all levels of the technical, institutional and social components of the systems, and the development.

### Criteria 2

Scenarios used to define and articulate system resilience include known risks as well as those of high uncertainty

### Criteria 3

The design and planning of the development incorporates technical, institutional and social enablers of resilience according to identified strengths and weaknesses of the systems and the development they are to be located in.

### Criteria 4

Cumulative expected benefits from the combination of distributed and centralised models have been assessed at multiple scales and found to be greater than for other alternative or conventional systems.

These are preliminary criteria only and it is recommended that further analyses of existing and planned developments are undertaken to inform their further development prior to their application to test their capacity to assess/predict system resilience. On-going validation and modification will improve their efficacy and relevance to stakeholders in urban development.



## 7. Conclusions

This pilot project has identified a wide range of technical, social and institutional enablers as influencing system resilience. Qualitative research focusing on two community-scale systems in Melbourne, one community-led and the other developer-led, has identified a gap in resilience assessment and proposes an approach that emphasises matching infrastructure system designs with an expected degree of uncertainty, through the analysis and incorporation of technical, institutional and social enablers.

Aurora, the developer-led system, and WestWyck, the community-led system, provide examples of innovative energy and water supply systems operating at different scales and locations. These were selected for the study following a survey of systems in Phase 1. It is important to note that while both systems have been in place for similar periods of time (less than a decade) they do exhibit key differences beyond the configurations of alternative energy and water systems. Firstly, Aurora is a much larger scale development and secondly, it is established in an outer fringe setting. In contrast, Westwyck is within an inner urban setting, and is occupied by households who in general are at more established life stages. These and other differences limit direct comparisons of performance and indicate the need for further research involving more cases from which to generalise patterns and findings (see below).

The adaptive and maladaptive practices of householders living with alternative systems under each type of institutional/governance arrangement was examined in Phase 2. The implications for resilience were found to be that; householders' knowledge (both learned and shared), their context in terms of priorities, finances and the design of the house/systems, and finally their capacity for agency, through community organisation and collective action, are significant enablers of resilience. Of all the social enablers, community cohesion, or social capital, emerged as a notable mechanism that is able to ameliorate certain technical and institutional challenges to system resilience, and supports long-term system resilience.

The different organisational arrangements surrounding both systems were identified in Phase 3. In providing for system resilience, this research established the importance of adaptive, integrated and inclusive design and management models, with clear lines of responsibility and cross-scale interaction.

The implications of wider uptake of these systems are discussed in Section 5.4, with the key outcome being a framework to address uncertainty. Preliminary criteria to assist policy makers in evaluating the resilience of new urban system options have been developed, with particular emphasis on the role of social adaption. What emerges from this pilot study is clear evidence that community resilience is associated with a complex interplay of technical and social factors. For policy, this means an emphasis upon social dimensions of community development and capacity is as critical as the provision of appropriate technical infrastructure in ensuring resilient urban systems in Victorian communities, in an era of climate variability.

## 7.1 Recommendations for future research

The value of this pilot research lies in the capacity of the findings to assist in the assessment and provision of resilient urban energy and water systems. However, as only two case studies were able to be investigated in this pilot project, the findings should be treated as indicative and preliminary. Further research is needed to verify and test their validity, in particular, (a) a longitudinal approach is needed to allow comparison of case studies over time, and (b) further case studies are needed across a broader and larger range of situations from which patterns can be generalised.

In particular, further case studies should examine the role (if any) of community scale in the development and maintenance of community resilience involving energy and water systems. The two case studies here are of quite different sizes but the dataset is insufficient to draw general conclusions about the role of scale at this stage. Further study should also include reticulated systems as a point of comparison with alternative and mixed systems, and involve longitudinal assessments of system resilience and the role of intermediaries in maintaining/increasing this resilience. This will inform the further development of the preliminary criteria for resilient urban systems developed here. These criteria would be available for policy makers, planners, developers and builders to ensure that our rapidly expanding population is a resilient one, prepared for short term faults and disturbances, as well as future uncertainty.

The adoption and use of assessment criteria for resilient urban systems would add to the growing number of tools emerging for assessing, evaluating or measuring the performance of urban areas according to various metrics. How resilience criteria might interact with these other measures, which include ecological footprinting, liveability and/or happiness indices, and other planning tools for urban sustainability emerging in Australia, is another area demanding further research to ensure that gains in one area do not result in perverse outcomes for another.

# Glossary

**Adaptive capacity:** The ability of technical, institutional and social components of a system to learn and adjust in response to a disturbance in order to maintain a desired outcome or change the nature of the desired outcome. Adaptive capacity is vital to a system's ability to increase or decrease its resilience. Two closely related concepts are 'maladaptation' and 'transformation'.

**Maladaptation:** Where a particular response - social, technical or institutional, to an actual or predicted disturbance weakens the system's overall resilience by exacerbating the impacts and/or hindering adaptation.

**Resilience:** The capacity of a system to absorb, adjust to or avoid shocks and disturbance without losing basic structures, functions or identity. The level of resilience in a system is an outcome of interactions between system components and the contextual environment. Resilience is therefore a dynamic state that can increase or decrease over time in response to changes in any one or more components. Resilience incorporates the concepts of adaptive capacity and transformation. A system's resilience therefore depends on its ability to avoid maladaptation and successfully adapt or transform to maintain a desired outcome or change the nature of the desired outcome. Resilience is a critical area of leverage for reducing system vulnerability.

**System:** A coherent arrangement of complex interacting components. For the purposes of this project, the systems in focus are the technical, social (which includes householders and communities) and institutional components and functions that together provide water and energy resources and services.

**Transformation:** A system's ability to change itself. May involve a deliberate change to structures, functions or identity, i.e. achieving a system 'transformation'. Transformation reflects a very high degree of adaptation, despite the loss of original system identity, provided this process is deliberate and results in desired outcomes.

**Vulnerability:** Shaped by the exposure, sensitivity and resilience of the person, system or community in focus, where exposure relates to the nature of disturbance encountered or projected, sensitivity refers to the technical and design characteristics of the system (e.g. location, durability, stress limits,) and resilience is a function of social, technical and institutional factors that determine what options are available to respond to disturbance.

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