A review of roadmaps for transitioning to a zero carbon built environment in Australia

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He would like to acknowledge the desktop research assistance provided by Loughlan Curran during his internship with the Victorian Eco-Innovation Lab.

Working paper for the Visions & Pathways project, March 2014

Research funded by the CRC for Low Carbon Living

Copy editor: Margaret Trudgeon

Report design: Jessica Bird

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Executive Summary

This paper outlines and critically 'maps' existing roadmaps relevant to transitions to a low or zero carbon built environment in Australia. A roadmap describes the measures required to achieve goals and/or map future innovation opportunities. The three questions addressed by a comprehensive roadmap are: Where do we want to go?, Where are we now?, and How can we get there?

The review identified 13 roadmaps/plans that have been produced by: peak industry bodies (Australian Institute of Refrigeration Air Conditioning and Heating); academic research groups (e.g. Sustainable Built Environment National Research Centre, Institute for Sustainable Futures); private consultancies; and non-profit research groups. Some were funded by peak bodies (e.g. Australian Sustainable Built Environment Council) or by state and federal government departments.

The identified roadmaps indicate the increasing attention on low-carbon transitions and important gaps and areas of divergence in existing analysis. The critical review draws on relevant theories of roadmapping, innovation management, sustainable urban development and governance. The key findings, with respect to the three overarching roadmap questions, are summarised below:

Where do we want to go?

- **The roadmaps focus on achieving highly divergent goals and most *do not* set a target for greenhouse gas emissions reduction**. Low-carbon related goals include: reducing the operational emissions of all existing buildings to zero in 10 years; making all residential buildings 'net zero carbon' by 2030; reducing Australia's emissions by 25 per cent below 2000 levels by 2020; and targets energy savings/reduced peak demand.
- **Highly *diverse potential pathways* to a future low-carbon built environment in Australia are competing for resources and reflect value-judgements/preferences.** The many areas of divergence identify competing agendas and areas of potential conflict. They also indicate the benefits of greater coordination and collaborative priority setting processes.

Where are we now?

- **The major finding is that roadmaps are informed by divergent assessments of: 1) the current state of low-carbon technologies, and associated priority technological and financial challenges; and 2) the urgency of climate action (i.e. required rapidity of de-carbonisation).** For example, some plans contend that existing, commercially available technologies can enable full decarbonisation; others dispute this assessment.

How can we get there?

- **Most roadmaps focus on existing Horizon 1 opportunities (e.g. commercially available technologies) and associated possibilities.** By contrast, roadmapping is traditionally conducted to 'map out' and plan the realisation of *future* technological or innovation trajectories (e.g. in high-tech industries such as the semiconductor industry).
- **Far greater emphasis is placed on technical innovation, rather than other major domains of innovation for sustainable urban development (i.e. innovation in the planning, design and management of urban development; and attitudinal and behavioural innovation)**. The interactions between these domains – which are emphasised by research on geographies of urban transitions – are also not addressed in most of the identified roadmaps.
- **The change assumptions and strategies that inform the roadmaps are also divergent, often reflecting different, underlying governance models.** The latter can be considered in terms of the 'classical steering', 'market-based' and 'policy networks' paradigms.

Additional key findings

- **Overall, most roadmaps fail to adequately address in detail the key question 'how can we get there?'** For example, often few details are typically provided on required policies, nor a clear set of prioritised steps to realise the goals/desirable future (implementation plan); and
- **Whilst decarbonisation of the built environment will involve multiple sectors (e.g. energy, construction, transport, telecommunications, and design) and their interaction, and many aspects of urban life, roadmaps tend to have a narrower focus on a single sector.** Some roadmaps explore some emerging interactions (e.g. see the "iGrid" Decentralised Energy Roadmap); however, they are not as advanced as leading international examples.

The findings of the review also have wider implications for efforts, within the CRC and elsewhere, to transition to a low or zero carbon built environments in Australia. In particular, it indicates that:

insufficient attention is being given to systemic, long-term nature of transitions

Most roadmaps focus on one sector, such as the energy sector, environmental control and cooling services (HVAC&AR), the construction industry, or broader built environment sector. This approach fails to deeply consider the interactions and convergence *between* sectors in low-carbon transitions. The roles of other sectors, such as telecommunications and automotive sectors, and their interactions with the built environment are not examined in detail. Additionally, a shorter-term focus on more incremental forms of change is typical of existing roadmaps. The difference between the dynamics of transitions of the identified roadmaps is presented below:

Table 1: The trouble with roadmaps...

Transitions and requirements for transition management (Rotmans, Kemp & Asselt 2001)	**Tendency of identified roadmaps** (i.e. most, not all roadmaps)
Multi-domain, multi-actor, multi-level	Single domain, produced by and/or for a single actor, envisaging change on one level
Long-term perspective (at least 25 years) for short-term policy; a 'basket' of visions	5–10 year outlook informing policy
Keep a large number of options open	Focus on single transition pathway
Try to bring about system innovation alongside system improvement	Mixed: many emphasise system improvements (e.g. increased efficiency, cleaner vehicles, etc); some also focus on system innovations.

important aspects of urban transitions are being inadequately considered, in particular:

- the roles of urban design, planning and management as an enabler of and barrier to change;
- individual and collective attitudinal change, and related lifestyle change dimensions;
- the need for more Horizon 3 innovation and thinking (as well as Horizon 1 and Horizon 2) focused on longer-term *step changes* and new urban planning systems/models;
- the convergence, interaction and co-evolution of transitions in *multiple* domains within urban contexts, such as in energy, transport, communication and infrastructure.

1. Introduction

This foreground paper assesses recently published roadmaps and plans to review existing thinking on low-carbon transitions and current 'roadmapping' practices. The research reviews public domain plans identified by desktop research and produced in Australia, such as roadmaps that have been commissioned by state or federal governments or produced by independent non-profit organisations (e.g. ClimateWorks). As such, the review does not consider roadmaps that Australian firms may have produced or analysis that governments have not made public.

Roadmapping is a tool that has, to-date, primarily been used in firms for strategic planning and technology management. The reports and plans reviewed here reflect emerging trends to develop future roadmaps for sectorial-level innovation and national change (see Box 1 below).

The central objectives of this paper are to: map existing thinking and change agendas regarding low-carbon urban futures (e.g. to identify the focal areas, gaps, areas of conflict); and critically consider the roadmaps in light of prospective urban transitions in Australia. The high-level 'mapping' of existing roadmaps draws on a framework of sustainable urban development that outlines domains where innovation is needed to move towards sustainable cities (Newton & Bai 2008), and the Three Horizons innovation framework, which originated in business management (Baghai, Coley & White 2000; Curry & Hodgson 2008), and has subsequently been used to explore innovation for achieving major sustainability transitions (e.g. see: Dixon et al. 2013; Newton 2007).

The paper is structured as follows: First, it provides an overview of roadmapping exercises and the existing roadmaps. This is followed by a more detail mapping of areas of shared focus and divergence. Brief comparisons are then made to similar studies conducted as part of the Post-Carbon Pathways and UK-focused Retrofit 2050 project, and by the Rocky Mountain Institute (see 'Reinventing Fire'). The concluding section summarises the key learnings for the CRC for Low Carbon Living, with a focus on the *adequacy* of existing roadmaps and gaps that can be addressed by its research.

Box 1: What is a "roadmap", and what are the key elements of a good roadmap?

The concept of a roadmap was developed in the 1970s as a way to conceptualise and communicate possible routes or a 'path' to achieving technological goals. For example, firms in the semiconductor industry frequently collaborate on roadmaps that coordinate and direct activities to develop next-generation circuits and other future semiconductor devices. Such roadmapping usually begins with a need (e.g. a market or product need), and then seeks to integrate an understanding of science and technology developments and projections *with* strategic business and product planning. More generally, and concisely, a roadmap has been defined as 'a sequence of measures designed to bring about a desirable future' (McDowall & Eames 2006). Others have argued that an *effective* roadmap is one that addresses three core questions to comprehensively assess both the present and the future:

1. *Where do we want to go?* i.e. what are the objectives that the roadmap will assist in achieving?
2. Where are we now? i.e. what is the current level of technology development, is there currently a market in place etc (e.g. what are the challenges in that market)?
3. *How can we get there?* i.e. what technology R&D is required, what policies need to be implemented, etc?' (Jeffrey, Sedgwick & Robinson 2013, p. 1016, emphasis added)

One way to assess a roadmap is to examine how comprehensively and clearly these questions are answered.

The literature highlights two further considerations. First, it is commonly argued that the *process* is more important than the end *product*, which directs attention to other outcomes, such as learning and the resulting impacts on stakeholder relationships (Jeffrey, Sedgwick & Robinson 2013; Sondeijker et al. 2006). For example, Sondeijker (2009, p. 19) argues that the key functions of participatory processes that explore desirable futures are to: enable social learning; and, it is hoped, 'fuel the emergence of the will and force for gradually bending the curve of development toward a comprehensive set of sustainability targets.' Second, practitioners argue the type of roadmap, and the roadmapping process itself that is used to develop the roadmap, must be aligned with the nature of the innovation or products they examine (Tierney, Hermina & Walsh 2013). For example, traditional roadmapping processes are inappropriate for innovations created at the interface of *multiple* root technologies and therefore requiring significantly different business models, such as those based on a consortia structure (Tierney, Hermina & Walsh 2013).

The use of roadmapping exercises has recently been expanded and diversified. Roadmapping practices have expanded from being used within firms for technology management and planning, to collaborative planning for achieving sector-wide goals and/or social goals (Amer & Daim 2010; Jeffrey, Sedgwick & Robinson 2013; Masum, Ranck & Singer 2010). These uses often have different objectives, such as influencing public policy, enrolling actors in a bold vision, or improving coordination. Often these roadmaps also have intended target audiences (Jeffrey, Sedgwick & Robinson 2013). In this case, an effective roadmap is one that succeeds in persuading and influencing these audiences.

2. Outline of existing roadmaps

Few roadmaps have been produced that envisage – or are relevant to – transitions to a low- or zero-carbon built environment in Australia. A total of 13 reports were identified, which, in many cases, can only be quite loosely classified as 'roadmaps', via desktop research and liaison with relevant experts and research groups (see the outline and *Table 2* below).[2] Due to the pace of technological and other relevant changes, only reports released in the last 10 years were considered. Additionally, boundaries were placed on the scope: the review focused on those that examined *decarbonisation* within the built environment and/or related technologies.

An overarching observation is that few roadmaps address *all* the questions, i.e. 'Where do we want to go? Where are we now? and How can we get there?'. For example, some reports – such as those produced by Beyond Zero Emissions (BZE) – do not include a clear sequence of measures describing *how* the desired future can realistically be achieved. That is, these 'plans' do not contain an implementation plan or prescribe necessary/enabling policies. This is an important consideration because BZE's plans are frequently considered to provide a comprehensive roadmap.

Other 'roadmaps' do not address the first question of 'Where do we want to go?' in much detail. For example, 'An Electric Vehicle Roadmap for Queensland', prepared in 2010 by the former Bligh state government, only sets vague, very short-term objectives. The subtitle of the report, 'An issues paper for public discussion', provides a clearer indication of the report's content.

Consequently, a useful distinction can be made between three categories of roadmap:

- **Category A:** Reports that are comprehensive roadmaps (usually with 'roadmap' in the title), which address a specific low-carbon built environment and/or emissions reduction objective(s). A good example is the 'iGrid Australian Decentralised Energy Roadmap'.
- **Category B:** Reports that do not meet all the expectations of a roadmap. The Zero Carbon Australian plans produced by BZE are a good example. As noted earlier, most reports in this category only vaguely answer the key question 'How can we get there?'.
- **Category C:** Reports that are, broadly speaking, 'in the ballpark' (addressing technological and/or urban futures), but cannot be classified as being a complete roadmap.

Table 2 (on the following page) below provides an initial outline of the identified roadmaps, placing each roadmap/plan in one of three categories and showing that they typically have a short time horizon:

2. Additional roadmaps and plans were identified but not analysed, including the Smart Grids Standards Roadmap produced by Standards Australia, and smaller-scale plans produced by ClimateWorks (e.g. for Geelong). Other reports such as 'The Pathway to 2020 for Low-Energy, Low-Carbon Buildings in Australia' were omitted because they principally provide the outputs of scenario/simulation-based modelling exercises and cannot be reasonably classified as a roadmap.

Table 2: Outline of identified roadmaps

Title (Lead author, YEAR)	**Time horizon**	**Summary**	**Category**
iGrid Decentralised Energy Roadmap (Institute for Sustainable Futures, 2011)	2017	Describes the current status and the potential of decentralised energy; focuses on identified market failures and related institutional barriers	A
Construction 2030 Roadmap of R&D Priorities for Built Environment Sector (Sustainable Built Environment National Research Centre, 2012)	2030 vision; (focuses on short-term actions)	A roadmap for R&D focused on six priorities, including: more 'intelligent' infrastructure and buildings, solutions for more sustainable built environment, development of new business models powered by new informational models, and use of ICT for radical redesign.	A
COAG Hydrogen Technology Roadmap (Wyld consulting group, 2008)	2020 vision (focuses on short-term actions)	Outlines a plan for enabling and facilitating the development of a hydrogen economy in Australia.	A
COAG Solar Thermal Roadmap (Wyld group consulting and McLennan Magasanik Associates, 2008)	2015 vision (focuses on short-term actions)	Outlines a plan for enabling and facilitating the development of a high-temperature solar thermal industry and technologies in Australia.	A
COAG Geothermal Industry Roadmap (Anon, 2007)	2013	Describes the current status of Australia's geothermal industry, strategies for growing the industry, and a detailed plan agreed by stakeholders.	A
ASBEC Zero Emissions Home Industry Roadmap (Institute for Sustainable Futures, 2012)	2030 Focus on shorter-term actions	Outlines steps for the building sector, all levels of government, and stakeholders to achieve 'Net Zero Carbon Housing'.	B
Zero Carbon Australia: Stationary Energy Plan (Beyond Zero Emissions, 2010)	2020 (10 year plan)	An approach to decarbonise stationary energy within a decade (using centralised solar thermal and wind power).	B
Zero Carbon Australia: Buildings Plan (Beyond Zero Emissions, 2013)	2023 (10 year plan)	An approach for retrofitting Australia's buildings to achieve 'zero emissions from their operation within ten years'.	B
Transition to low-emissions HVAC&R: Issues and solutions (Discussion paper) **(**The Australian Institute of Refrigeration Air**,** Conditioning and Heating, 2013)	Not defined	Examines potential transitions to low-emissions heating, ventilation, air conditioning, and refrigeration (HVAC&R). Proposed roadmap has five pillars: Professionalism, Regulation, Information, Measurement, and Emission abatement ('PRIME').	B

Low Carbon Growth Plan for Australia* (ClimateWorks Australia, 2010) **Also see the city and regional reports*	2020	Emissions reduction strategy identifying how Australia can reduce GHG emissions by 25% by 2020 at low cost.	B
An Electric Vehicle Roadmap for Queensland (Queensland Government, 2010)	2011 (1 year plan, contribute to 2020 targets)	The roadmap outlines actions the Queensland Government has and will take to enable adoption of electric vehicles to help reduce emissions.	B
Building Construction Technology Roadmap (Warren Centre for Advanced Engineering & Copper Development Centre, 2004)	20 years: explores dwellings in 2025	Explores new, emerging technologies 'as they will affect the infrastructure and building construction industries in 20 years' time, with particular reference to home building, and including, but not limited to, applications for technologies involving copper'. 'Roadmap' has no priorities or implementation plan.	C
Enabling Technology Futures Survey (Australian Institute for Commercialisation – prepared for the Federal Department of Industry, Innovation, Science, Research and Tertiary Education, 2012)	Three horizons: Horizon 1 (now); Horizon 2 (next decade); and Horizon 3 (20yrs)	Provides a view of the current and future applications of nanotechnology, biotechnology and synthetic biology – including their drivers, opportunities, risks, barriers, and disruptive potential.	C

A second observation is that most roadmaps were typically prepared (and/or are championed) by one organisation. Some plans draw on extensive stakeholder consultation (e.g. see: Bok et al. 2012); however, none can be considered to be a deeply collaborative roadmapping exercise. This makes Australian practice inconsistent with international trends. Roadmapping is increasingly used as 'a method for bringing a number of interested parties together to develop a pathway' to achieve shared objectives (Jeffrey, Sedgwick & Robinson 2013, p. 1017).

A third initial observation is that existing roadmaps tend to have very different innovation and/or technological priorities. As noted in the introduction, the Three Horizons innovation framework will be used in to help with mapping this dimension. The framework is outlined in Box 2 below:

Box 2: The Three Horizons framework

The Three Horizons innovation framework is referred to by some reviews of roadmapping studies and potential urban innovations (Dixon et al. 2013; Newton 2007; Newton & Bai 2008). There is no consensus on the nature and timeframe of each horizon, which are partly context dependent. In a business context the Three Horizons refer to a firm's current core business (Horizon 1), newly emerging opportunities for building new businesses (Horizon 2), and 'seeding' options for the longer-term future (Horizon 3). In general usage, these terms can be understood to refer to the present, short- to medium-term, and long-term time horizons. Progressively more uncertain and disruptive innovations are associated with Horizon 2 and Horizon 3 respectively.

Newton (2007) defined the Three Horizons as follows: Horizon 1 innovations are capable of *immediate* implementation (e.g. as a result of their relative maturity of development, supportive policy settings, etc); Horizon 2 innovations are framed as those capable of *bridging* from the present situation to future sustainable infrastructure and processes, and can be widely implemented (next-generation of innovation such as natural gas and distributed energy systems); while Horizon 3 innovations are only implementable over the *longer term* (15–20 years out) and will 'enable a step change in system performance, but currently face significant barriers to take-up and diffusion' (Newton 2007, p. 573), e.g. ultra-smart buildings linked to a new sensor-rich city infrastructures, a new solar-hydrogen economy). It is further argued that in current urban planning systems, 'H1 and, at best, H2 thinking tends to dominate' (Newton 2007, p. 574).

Another useful technology-focused definition is provided in the emerging 'enabling technologies' review conducted by the Australian Institute of Commercialisation (2012), as follows:

- *Horizon 1*: existing technologies that are being *commercialised*.
- *Horizon 2:* future technologies *currently under development* (they are at the 'lab bench' stage) with expected commercialisation within the next decade or so.
- *Horizon 3:* 'blue sky' research with highly uncertain, longer-term prospects.

Newton presents these Three Horizons visually in the following figure:

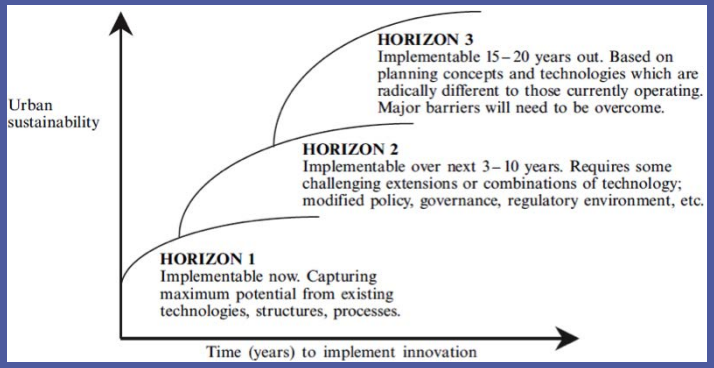

Figure 1: Three Horizons of planning (Newton 2007, p. 572)

Applications of the Three Horizons framework often have a technological orientation, rather than a socio-technical orientation, as seen, for example, in Bishop (2012). Newton has experimented with adapting and extending the model so that it is also applied to urban planning/governance and design, and to attitudinal and behaviour change (see: Newton & Bai 2008).

The framework is also used, and has been further adapted, in some foresight exercises (e.g. Curry & Hodgson 2008; Sharpe & Hodgson 2006). In one model, evolving viability in a changing external 'environment' is added to the initial basic framework – e.g. Horizon 1 refers to prevailing or dominant systems/views that are well adapted to the current external environment and expected to lose 'fit' over-time as the environment changes; Horizon 3 has the exact opposite profile; and Horizon 2 is an unstable intermediate space (Curry & Hodgson 2008). This model also highlights how the Horizon 1 'business-as-usual' view is often challenged by the new perspectives offered by Horizon 3, pointing to disruption points that may also emerge. Others have integrated Three Horizons thinking in scenario-building processes (Schultz, Crews & Lum 2012).

A second table below compares existing roadmaps and plans, examining: the targets/objectives, technological and innovation priorities (e.g. the innovation horizon[s] as per the Three Horizons framework), and change strategies and associated assumptions that frame the analysis. (NOTE: the three COAG energy technology roadmaps are summarised in the same column, and one category C report – Building Construction Technology Roadmap – is not outlined in Table 3).

Table 3: Comparison of major roadmap objectives, priorities, and assumptions

Roadmap / Plan	BZE Stationary Energy Plan (Zero Carbon Australia)	BZE Building Plan (Zero Carbon Australia)	iGrid Decentralised Energy (DE) Roadmap	COAG Energy Roadmaps	ClimateWorks Low-Carbon Growth Plan	Construction 2030 R&D Roadmap	ASBEC Zero Emissions Homes Roadmap	AIRAH low-emissions HVAC&R	Enabling Technology Future Survey	Queensland Electric Vehicle roadmap
Targets and timeframes	-100% stationary energy from renewable energy sources by 2020	-Reduce operational emissions of existing stock to zero by 2022 (10 years)	-Short-term plan -Calls on Federal government, with industry, to establish 2017 targets for DE (energy savings; less peak demand)	-2015/2020 visions -Shorter-term targets for market and industry development	-Overall target: 25% reduction in Australian GHGs by 2020 (also produced local and regional plans)	-See 9 visions in "Construction 2020" -Overall vision is for the industry to take more responsibility for leading and investing in research and innovation.	-Proposes target: all residential buildings to be 'net zero carbon' by 2030 (also earlier targets for *new* detached & *new* semi-detached dwellings)	-Goal: transition to low-emissions; and "a highly skilled and professional Australian HVAC&R Industry that is safe, cost-effective and environmentally effective."	None	-Support EV uptake -Linked to former Labor government's target (reduce GHGs from household fuel and energy use by one-third by 2020)
Technology priorities	-Renewables (combining solar thermal + wind) -Centralised energy grid via solar thermal	-Retrofitting technologies to reduce energy demand/usage -Distributed energy generation (PV)	-Shift to a 'smart grid'; more decentralised energy supply (e.g. solar photovoltaic) -Adopt electric vehicles as a decentralised energy resource (also feed into the grid)	-Hydrogen, solar thermal, geothermal - stationary energy (both centralised and distributed generation), transport (transit and personal), and portable energy	-Energy: short-term opportunities (e.g. shifting from coal to gas); renewables also -Improving conventional vehicles internal combustion) -More energy efficient technologies (building products, appliances)	-Enabling technologies for: materials, design, building sub-systems (ICT, nanotech / advanced materials, biotechnology; Intelligent buildings)	-N/A (industry roadmap)	Technologies to address/reduce: -System efficiency -System load and energy consumption -Carbon intensity of energy sources	-Enabling technologies with broad application throughout economy – nano, bio, synthetic biology – that could address national challenges	-Electric vehicles plus adoption of 'smart grid' technologies
Innovation horizon(s)	-Horizon 1	-Horizon 1	-Focus on horizon 1 -Some discussion of 'horizon 2' (electric vehicles and storage)	-Horizon 1 and 2	-Horizon 1 technologies	-Mostly Horizon 1 and Horizon 2; some thought to horizon 3	-N/A (Focussed mainly on industry building / change processes)	- Horizon 1 and 2	-Three horizons	-Horizon 1

Change priorities	-Technological solutions (Note: behavioural change is *implied* by the mode shift to public transport)	-Technological solutions -Retrofit of existing building stock	-Combination of technology and some behaviour change (e.g. energy efficiency, peak load management)	-Market and supply chain development – e.g. via large-scale demonstrations projects, industry building processes	-Combination of technology and some behaviour change	- Building information models / related new business models - 'Intelligent' buildings / infrastructure - Use of new enabling technologies - Educational curricula	-Building sector engagement and collaboration	"PRIME" roadmap: -Professionalism -Regulation -Information -Measurement -Emission abatement	-None: a general survey of emerging technologies	-Technological solutions (as well as the supporting infrastructure)
Approach to change	-Establish technical feasibility to help enable the required changes to occur (doesn't address necessary policies or political changes) -Secure visionary political and other leadership e.g. from business; non-market measures central	- Legislative/ policy intervention to ensure adequate implementation.	-Focus on policy changes to address institutional barriers to decentralised grid and improved energy efficiency (this will drive change e.g. via corrected incentives, greater information, policy coordination)	Enable via: -Policy framework -Knowledge building -Market and supply chain development -Training	-Focus on winning support from key industry sectors as a basis for winning broader support. -Carbon price ($20 to $30/tCO2e) plus other interventions to address other barriers.	-Focus is on greater industry R&D -Greater collaboration within the sector and influential leadership	-Standard setting, design guidelines -Coalition-building -Business case development/tools -Industry-building -Rating tools -Branding and communications	-Strong focus on improvements to measurement, supporting tools, and better engaging "end users" (of HVAC&R) -Recognises roles for government in development of regulations and incentives -Skills training	Market-led process (not techno-push) dependent on: -"Market-pull" commercialisation (demand driven) -Absorptive capacity of firms and industries -Collaboration - Ongoing R&D support	-Land-use planning -Necessary to harmonise standards and regulation -Address emerging infrastructure needs (to support EVs, and for smart grid)
Additional assumptions	-Assumes complete electrification of transport and heating within ten years (note: those costs are not included in this plan)	-Assumes that a zero emissions grid exists (i.e. implementation of BZE's 'Stationary Energy Plan')	-Assumes a shift away from large-scale centralised energy	- Market and supply chain uncertainties must be addressed	-Assumes that costs and benefits excluded from analysis are immaterial to the overall conclusions.			- HVAC&R industry needs to develop a coordinated strategy (addressing diversity and fragmentation)		-Shift to EVs cannot be left to the market: i.e. requires government planning and oversight

3. ‘Mapping’ the roadmaps

Areas of divergence and conflict: targets and timeframes (‘Where do we want to go?’), and change assumptions and strategies (‘How can we get there?’)

Targets and timeframes

As summarised in *Table 3*, most roadmaps focus on highly divergent goals – e.g. some are focused on industry development, whereas others focus on broader sectorial or system transformation goals. An important area of divergence is whether or not greenhouse gas emissions reduction targets are set, and the proposed timeframes to achieve them. Targets range from decarbonisation of a sector within 10 years, to 25 per cent reduction by 2020, to a target for all residential buildings to be ‘net zero carbon’ by 2030.

Table 4 outlines the contrasting emissions reduction targets in existing roadmaps; however, most roadmaps/plans do not include an overarching target for greenhouse gas emissions reduction.

Table 4: Greenhouse gas emissions reduction targets and associated goals

Roadmap	Emissions reduction target?	Associated goals?
Beyond Zero Emission Stationary Energy Plan (Zero Carbon Australia)	Completely decarbonise Australian stationary energy sector within a decade (by ~2020).	Avoiding 2 degrees of warming; 350 ppm viewed as boundary (safe level of carbon dioxide)
Beyond Zero Emissions Building Plan (Zero Carbon Australia)	Reduce operational emissions of existing building stock to zero within a decade (by ~2022)	See above
ClimateWorks Low Carbon Growth Plan	25% reduction in Australian greenhouse gas emissions by 2020	
iGrid Decentralised Energy Roadmap	5-year target (post-initiation of implementation) for ‘10 million tonnes of carbon dioxide avoided’	Sets targets for energy savings and peak demand reduction. Overarching goal is reconciling sustainability and affordability
ASBEC Zero Emissions Homes Roadmap	No target	Advocates for the industry setting targets for all residential buildings to be ‘net zero carbon’ by 2030, and setting interim targets for building types
Queensland Electric Vehicle Roadmap	No target	Linked to former Labor state government’s target to reduce greenhouse gas emissions from household fuel and energy use by one-third in a decade (by 2020)
Construction 2030 R&D Roadmap	No target	
COAG Geothermal Roadmap	No target	
COAG Solar Thermal Roadmap	No target	
COAG Hydrogen Energy Roadmap	No target	
Building Construction Technology Roadmap	No target	
Enabling Technology Future Survey	No target	

Some roadmaps incorporate a sequence of short-term, medium-term and long-term targets. The ASBEC Roadmap advocates setting a target for all residential buildings to be net zero carbon by 2030, and setting interim targets for different building types (starting initially with new detached and then new attached dwellings, including apartments, followed by established homes and attached dwellings. The roadmap argues that 'in the residential sector, by far the greatest challenge lies in the upgrading of existing housing stock which represents the vast majority of housing' in Australia.

The above summary also identifies major areas of divergence. For example, the Beyond Zero Emissions (BZE) Building Plan focuses on existing building stock, whereas the ASBEC Zero Emissions Home Roadmap advocates an initial focus on new dwellings. Additional areas of divergence are noted below, focusing on the envisaged and preferred low-carbon futures articulated in the roadmaps.

Envisaged low- and zero-carbon futures: contrasting themes and foci

A number of roadmap themes highlight key areas of diverging and conflicting visions:

1. **Reliance on existing Horizon 1 technologies** (e.g. current solar thermal power technologies) **vs adopting emerging and future technologies** (e.g. a 'hydrogen economy', or Horizon 3 technologies that may be developed in nanotechnology and synthetic biology research programs to enable new clean energy and build environment solutions):

Horizon 1 examples:

- the BZE Stationary Energy Plan states that 'the Plan relies only on existing, proven, commercially available and costed technologies [i.e. focuses on Horizon 1 technologies]. The Plan found that wind and concentrating solar thermal (CST) power with molten salt heat storage are the most appropriate, cost effective, commercially available, and scalable technologies for deployment in Australia' (p. xvii).
- 'the iGrid Research program [for decentralised energy] is particularly concerned with supporting distributed energy resources that are already technologically and economically viable' (iGrid Research Program Working Paper 4.a).

Horizon 2/Horizon 3 examples from the Enabling Technology Future Survey include:

- Emerging functional materials, responsive to external environments (e.g. adaptive nano-materials/technologies for energy-efficient buildings, such as smart windows);
- Horizon 2: advanced photovoltaic systems using engineered nanomaterials (e.g. for building-integrated photovoltaics); nano-structured catalysts in fuel cells; and
- Horizon 3: hydrogen production, storage technologies and use.

2. **A limited shift away from existing transport modes** (e.g. via adoption of private hydrogen fuel cell vehicles, or electric vehicles) **vs major modal shifts towards public transport and other forms** (e.g. walking and cycling; locating services and work closer to where people live).

3. **Limited decentralisation** (i.e. centralised large scale zero-

3. BZE excluded small-scale photovoltaic solar power technologies on cost and technology efficiency grounds, although the subsequent Buildings Plan (released 3 years later) included distributed energy generation.

4. Note: the iGrid vision may be problematic to achieve in practice, given trends towards greater densification in urban form. This urban form requires new energy technologies in order to achieve the desired penetration of distributed energy resources, e.g. building-integrated photovaltaics (Newton & Newman 2013).

emission energy supply, e.g. solar thermal power plants) **vs new distributed systems including a new 'intelligent' energy grid** (new system of distributed energy, with advanced electricity network control systems).

- The roadmaps indicate different views on the desirability of retaining a centralised grid (as occurs in the Zero Carbon Australia Stationary Energy Plan), or moving rapidly towards a mostly decentralised energy (as per the iGrid roadmap) – and the mix of technologies that would provide this distributed generation (e.g. only renewables, or co-generation).

4. **Supply-side focus** (decarbonising energy supply; new low or zero-emission transportation technologies) **vs consideration of both demand management and supply** (incorporating measures to change behaviour, 'peak load management for reduced energy usage, etc).

Change assumptions and strategies

The 'How can we get there?' question is often partially addressed. In some cases this is intentional, such as the 'plans' produced by BZE. BZE 'deliberately remained agnostic' about implementation, financing requirements and political aspects and instead focused on technical issues (Lucas 2012). However, despite this partial analysis, an interesting point of comparison is what core assumptions or beliefs about change have informed the roadmaps/plans and the organisations that produce them.

In some cases this reflects the common dichotomy between 'demand pull' and 'technology push' change (more on this below). In others, it reflects an emphasis on – or preference for – particular governance strategies (see Table 5 below). In many cases, the roadmaps/plans either specify necessary roles for government or imply direct regulatory measures (and associated political leadership) for realising their vision of the futures. In some cases, contrasting industry-led change processes are emphasised (e.g. the ASBEC Zero Emission Homes Industry Roadmap).

Table 5: Three general governance paradigms (Elzen & Wieczorek 2005)

	Classic steering (top-down, 'command-and-control' model)	**Market model** (bottom-up)	**Policy networks** (processes and networks)
Foundational principles	Classic political science	Neo-classical economy (rational actor model)	Sociology, innovation studies, neo-institutional political science
Perspective	Centralised; hierarchical organization	Local actors	Interaction between actors
Characterisation of relationships	Hierarchical	Autonomous; self-organisation	Mutually dependent
Governance instruments	Formal rules, laws, regulations	Financial incentives	Learning processes, network management (e.g. experiments, demonstration projects, network building, visioning or scenario processes)
Characterisation of interaction process	Neutral: implementation of formulated goals	Self-organisation on basis of autonomous decisions	Interaction processes in which information and resources are exchanged

An additional over-arching consideration relates to the common assumptions of linearity (Sondeijker 2009) which can frame the outlook and plan contained in a roadmap. There is often a tendency to consider a single desired future, rather than multiple scenarios and divergent *pathways*.

Below is a summary of some of the major change strategies proposed in the roadmaps:

- *Policy intervention in current institutional barriers to change:* The iGrid roadmap and ClimateWorks plans both emphasise the need for actions to address institutional barriers to energy efficiency and decentralised energy. A simple example is 'split incentives' between renters and owners which often disincentive investment. The iGrid roadmap also proposes central government coordination of decentralised energy policy and greater overseeing by a national government agency.

As noted by Lucas (2012), the lead author of the Zero Carbon Australia plans, Beyond Zero Emissions (BZE), favours the use of direct regulatory measures to drive change, i.e. classic steering, and opposes use of market mechanisms such as emissions trading schemes. BZE is also highly skeptical of the carbon pricing approaches advocated by other organisations, such as ClimateWorks (Lucas 2012).

- *Market and supply chain development:* COAG reports have a strong emphasis on building local supply chains, markets, and technical capacity. For example, the hydrogen technology roadmap proposes 'large-scale demonstration projects, which stakeholders noted would pull and underpin: R&D; technology, industry and policy development; regulations, codes and standards; and overseas interest in Australia as a market' (p. iii). Such projects adopt a 'policy networks' approach.

- Coalition-building and advocacy: The ASBEC Zero Emissions Home Industry Roadmap has a strong focus on coalition-building and collaboration, and education via information provision and new tools. The former is envisaged to be actioned through a new 'Net Zero Energy Alliance', which would include both private and public sectors actors. Similarly, COAG roadmaps propose the establishment of new advocacy groups in Australia (such as a hydrogen and fuel cell industry association).

- *Technology forcing:* Innovation studies scholars define 'technology forcing' as the intentional use of standards, regulation and other government policies to better link technology and science to societal goals [24]. Variants of this are included in the COAG roadmaps. For example, for the Hydrogen Technology Roadmap, one key recommendation is for the use of government purchasing policies favourable to hydrogen and fuel cell products as a push strategy. Although technically a demand-side approach, it involves policies that influence the design of and market demand for technologies – which can work to 'force' private sector investment and innovation – rather than focusing on serving existing customer demand. Such roles for government have also been more widely advocated by The Australian Academy of Technological Sciences and Engineering (McGrail 2012), as technologies need early markets in order to advance (e.g. from government purchasing/procurement).

- *Demand-driven commercialisation strategies:* While the Enabling Technology Futures survey notes the role of government (e.g. in creating a regulatory environment that ensures responsible use and development of such technologies), it most strongly emphasises 'the need for demand driven commercialisation strategies that focus on developing new products and services to address existing problems and challenges' (p. 5; also see Chapter 9). Similarly, business model innovation to 'allow firms to enter into new market spaces' and developing absorptive capacity ('the ability to recognise valuable new enabling technologies and apply them to commercial ends', p. 5) are also seen as priority change mechanisms for Australian industry to effectively adopt enabling technologies.

The roadmaps can be mapped simply on a continuum from market-pull to policy-push (Figure 2). Roadmaps with equal elements of both change strategies are placed in the middle.

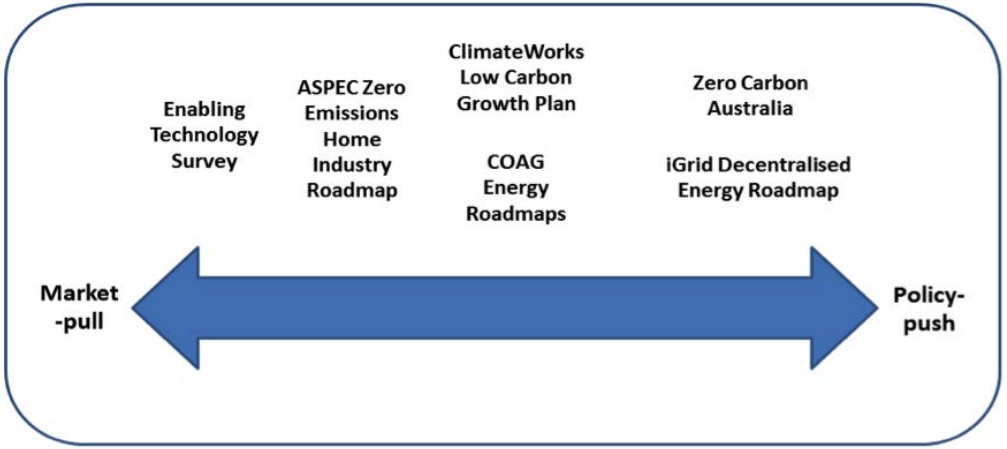

Figure 2: Orientation towards policy/regulation-push or market-pull

Innovation for sustainable cities: Which dimensions are emphasised or envisaged?

Previous studies have found that three principal domains of innovation are required for achieving sustainable urban development: 1) innovation in the planning, design and management of urban development; 2) technological innovation; and 3) shifts in individual and collective attitudes towards the built and natural environments and associated lifestyle change to addresses consumption issues (Newton & Bai 2008).

Figure 3 summarises the degree to which each domain is addressed in each roadmap. A roadmap/plan placed in the middle of the triangle equally addresses all three innovation domains; placement closer to a corner represents emphasis on that domain of innovation.

Figure 3 clearly shows the core focus on technological innovation in most roadmaps, which is unsurprising given this is normally their focus. It also shows that only two – the iGrid Decentralised Energy Roadmap and ClimateWorks Low-Carbon Growth Plan – envisage behavioural change. IGrid has integrated technological and behaviour change (hence, it is placed in-between them), including measures to incentivise energy efficient behaviours, modifying the timing of energy use according to energy prices and demand (as part of 'peak load management' strategies and variable pricing), and use of smart meter technologies to proactively manage electricity usage and spending.

Some behavioural changes are *implied*, but not explicitly addressed in the plans. For example, the Zero Carbon Australia Stationary Energy Plan assumes full electrification of urban transportation – which includes a large mode shift to public transport (as well as electrification of vehicles).

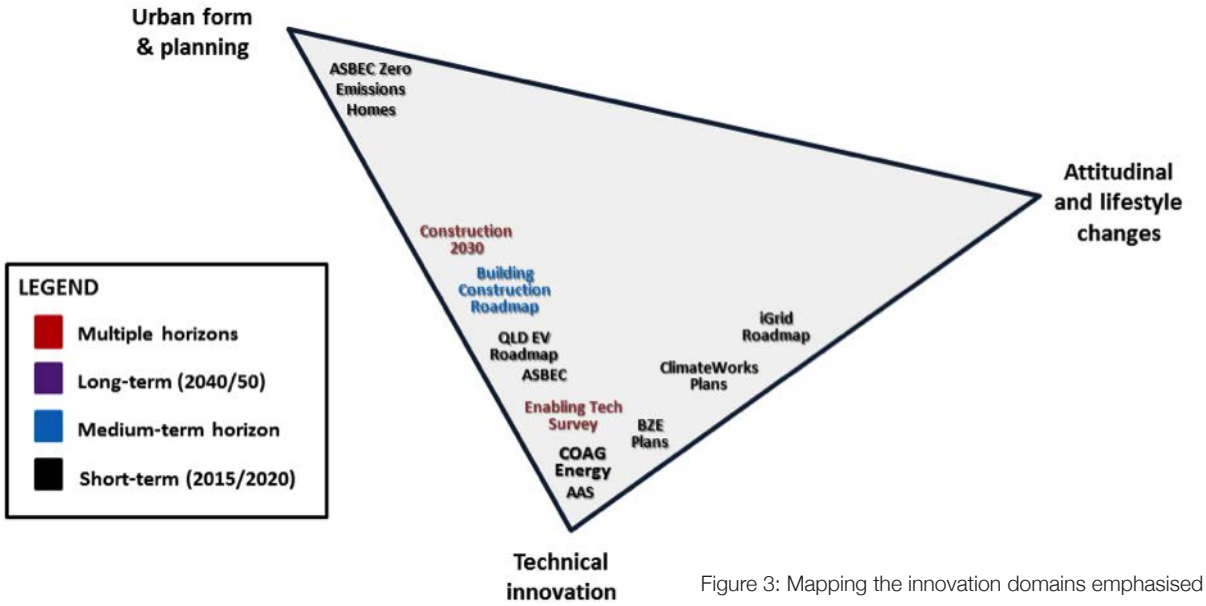

Figure 3: Mapping the innovation domains emphasised in the roadmaps

Roadmaps generally do not address the planning, design and management of urban development. The Queensland Electric Vehicle roadmap does note land-use planning and urban infrastructure issues. This includes planning for electricity grid impacts, and for recharging facilities. Another important exception is the Construction 2030 R&D Priorities Roadmap. Priority 4 – 'Information and communications technology for radical redesign' – focuses on new forms of advanced multi-scale redesign of housing, city-level and urban design (small and intermediate scales). This R&D priority focuses on how changes in these design practices could be enabled by ICTs such as predictive tools and techniques for integrated design and optimisation, modelling technologies, and other new urban design solutions (Bok et al. 2012). This R&D roadmap also notes that the move towards green buildings is contributing to a wholesale rethinking of design and construction processes.

Sectorial emphasis and emerging interdependencies

A further way to examine and map the roadmaps is to consider the *sectorial* emphasis – that is, the degree of emphasis on, or integration of, housing/buildings, energy production, and/or transport (see *Figure 4* below). These sectors reflect the core focus of low-carbon transition roadmaps on: energy production and usage, and related drivers of energy consumption, e.g. needs for housing/comfort, cooking and transportation (Shove 2003). In greenhouse gas accounting terms, the focus is on Scope 1 (directly produced within cities, such as from vehicles and household gas usage, etc) and Scope 2 emissions (indirect emissions via the energy that is consumed), and *not* on Scope 3 emissions, which are outside the scope of this review. A more comprehensive assessment would also include Scope 3 and consider emissions associated with consumption (e.g. from agricultural production).

The ClimateWorks Low-Carbon Growth Plan is the most holistic. It describes potential emissions reductions in buildings and household energy use, transport, and the power sector (electricity). However, the plan does not discuss urban planning and/or land-use dimensions.

Figure 4 also indicates emerging interconnections and interdependencies. Most common are energy and transport links, considering the energy/grid requirements of electric vehicles, and how electric vehicles could contribute to a future 'smart grid'. The COAG Hydrogen Technology roadmap gives close to equal weight to transportation and stationary power. The latter may incorporate the use of fuel cells for distributed energy generation, and/or residential fuel cell co-generation systems. The Zero Carbon Australia Buildings Plan prescribes a mixture of retrofitting technologies for existing building stock (to reduce household energy demand) and distributed generation. It argues that through the use of solar energy technologies, homes can become 'renewable energy power stations' – however, trade-offs between photovoltaic technologies and densification (Newton & Newman 2013) are not discussed.

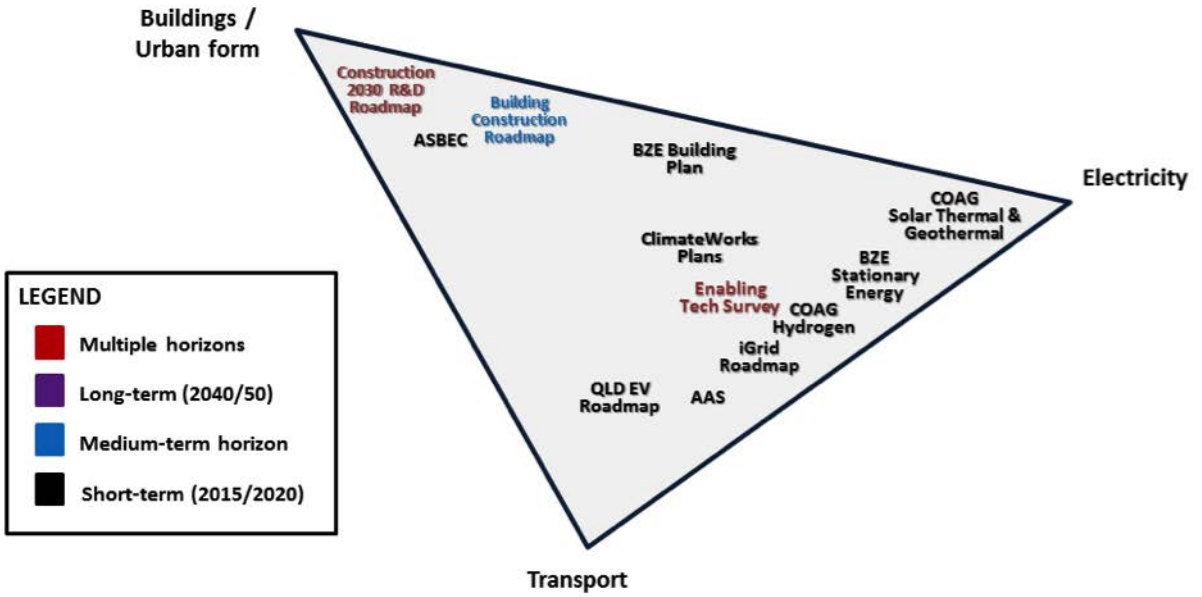

Figure 4: Mapping the sectorial emphases in existing roadmaps

4. Comparisons with other reviews and international plans

Comparisons with similar reviews

- *Post-carbon Pathways project:* This meta-analysis of transition strategies found the most common assumption was that transformational change needs 'visionary political leadership combined with broad community mobilisation', and 'most strategies analysed ultimately supported the notion that the need to secure and sustain broad social and political support is the greatest obstacle' (Wiseman, Edwards & Luckins 2013, p. 88). Some of the Australian roadmaps are consistent with this analysis. Others envisage transformational changes being more industry-led (E.g. the Zero Emissions Home Industry Roadmap), or driven by a complex combination of technological change, demand-driven commercialisation strategies, and industry-building and collaboration strategies.

- *Retrofit 2050 project:* This review of UK and European roadmapping studies found that they typically 'focus on identifying a series of intermediary steps, over a shorter time horizon, towards a more specific goal' (Dixon et al. 2013). The Australian studies are broadly consistent with this. Most have a short-term time horizon and, linked with this, focus on existing Horizon 1 innovations.

It is also argued that UK and European roadmaps in the context of 'low carbon' are too focussed on energy and associated carbon emissions and, consequently, fail to adequately address the multidimensional challenge of urban sustainability. Roadmapping in Australia is consistent with this finding. In some cases "sustainability" is also centrally framed as reduced greenhouse gas emissions ("IGrid Roadmap"). The Building Construction Technology Roadmap is a notable exception – it is more holistic addressing energy, broader services (e.g. water, waste, etc), and other housing functions such as entertainment and communications, but has very little emphasis on emissions reduction.

Comparisons with innovative international studies

The Rocky Mountain Institute's (RMI's) 'Reinventing Fire' project provides a relevant, thought-provoking comparison (Lovins 2011). It is RMI's plan for how the United States can – they argue – stop using oil and coal by 2050 (and one-third less gas). It articulates a vision of business-led and market-based solutions in four sectors: transportation, buildings, industry and electricity. The plan outlines ways to integrate action in these sectors, e.g. via linked innovations. The plan concentrates on:

- four different tools driving energy transformations: technology; public policy; integrative building design; and novel business models (and associated competitive strategies);

- two core elements: using energy much more efficiently in buildings, vehicles, and factories; and more diverse and distributed energy supply from renewable sources.

The plan aims to show: the potential benefits of adopting *and* integrating smart grid, smart building systems, and electrified vehicles; how to triple or quadruple the 'energy productivity' of buildings (e.g. through integrative building design and improved materials); how the shift to distributed renewable energy sources, such as solar and wind power, is eased through this reduction in energy demand; and that greater adoption of variable renewable energy sources is possible (more than is widely believed) via smart grid management systems. It also includes proposed measures to reduce vehicle use (e.g. via urban design and planning, new form of road charges, IT-enabled car and ride-sharing), and to switch fuels to hydrogen fuel cells, electricity and advanced biofuels.

RMI's chief scientist Amory Lovins provocatively argues that the key to solving the energy problem is by 'enlarging' it, and taking a much more holistic approach.

Similar to the Zero Carbon Australia plans, RMI's plan for 'Reinventing Fire' can be placed in Category B. It falls short of providing a full answer to 'How do we get there?' (e.g. it doesn't include a detailed implementation plan and/or financing details), and, given it was prepared by one organisation, it also relies on persuading target audiences (rather than influencing via inclusion in the process).

5. Conclusions and observations about the use of roadmapping for urban transitions

One way that roadmaps can be evaluated is by how comprehensively (or not) they address the three strategic questions: Where do we want to go? Where are we now? and How can we get there? Existing roadmaps either do not address or poorly address the third key question. This potentially represents a gap in knowledge regarding the most suitable or effective change strategies. As noted, in some cases organisations preparing roadmaps intentionally avoid these aspects (Lucas 2012). Additionally, there is very little agreement on 'Where do we want to go?' and within what timeframe.

In addition, this mapping exercise, along with reviews of key trends in Australian cities (Newton & Newman 2013), suggests that important aspects of urban transitions are being inadequately considered, in particular: the roles of urban design, planning and management as an enabler of and barrier to change; individual and collective attitudinal change, and related lifestyle change dimensions; and the need for Horizon 3 innovations and thinking (as well as Horizon 1 and Horizon 2 planning).

The use of suitable roadmapping methodologies is also an important consideration. This review found that most existing roadmaps were typically prepared (and/or are championed) by one organisation, although stakeholder *consultation* was a key input into many. Transition practitioners and scholars have argued that new and revised approaches to roadmapping are required for advancing systemic innovation and for transition management – such as being developed in more participatory ways (Dixon et al. 2013; Jeffrey, Sedgwick & Robinson 2013; McDowall 2012), and being continually updated and 'alive', not run as a one-off exercise (Eames et al. 2013). As noted earlier, in Australia we are yet to see sophisticated collaborative roadmapping where it is used as a technique for bringing multiple parties together to develop a 'pathway' for achieving shared objective(s). There is an opportunity to pioneer the use of such approaches that can help to answer 'How can we get there?'.

Finally, the use roadmapping *for* urban transitions could usefully draw on the recent findings of other urban transition initiatives in Europe. The European Urban Transitions Lab project found that the convergence, interaction and co-evolution of multiple transitions is a crucial feature and challenge of the urban context (Nevens et al. 2013). They argue this 'implies working across different dimensions as well as on different levels simultaneously' (Nevens et al. 2013, p. 115). This is a major challenge for roadmapping exercises and suggests that more attention to multi-regime interactions is required (Konrad, Truffer & Voß 2008; Lovins 2011; Truffer, Voß & Konrad 2008). Existing roadmaps for transitioning to a low- or zero-carbon built environment fail to explore this in adequate detail. However, future Zero Carbon Australia plans – led by Beyond Zero Emissions – may adopt these approaches.

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Appendix: Longer summaries of two important plans/roadmaps for a low-carbon future

Zero Carbon Australia (Beyond Zero Emissions)

Beyond Zero Emissions (BZE) is developing a blueprint for transitions to a decarbonised Australian economy. The Zero Carbon Australia Project consist of six transition plans that will cover energy (completed), buildings (completed), land use (to be completed in 2014), transport (to be completed in 2014), industrial processes (to be completed in 2016), and the replacement of coal exports.

Three core elements of this still-developing blueprint are:

- a rapid shift of energy and transport systems to being **powered by 100 per cent renewable energy sources.** The BZE Transport Plan will present a plan to power transport fully by renewable energy, achieved via shifts to electric rail, electric vehicles and biofuel hybrids;
- **electrification** of activities that currently use fossil fuels, such as home heating and cooking (via new appliances), and transportation (shift to electric vehicles, public transport);
- **major reductions in energy use** achieved via a wide range of energy efficiency measures.

Adjacent is a summary of the two completed plans for stationary energy and existing buildings:

Plan	Core elements / proposals
Stationary Energy Plan	• Transition to zero emissions energy within 10 years. • Maintain a national grid, providing baseload power via a combination of concentrated solar thermal power (60% of electricity) and wind power (40% of electricity); grid back-up to be provided by hydroelectric power and some biomass. • Halve total energy demand – from ~4000 PJ/yr (Petajoules per year) to well under 2000 PJ/yr, via the efficiency gains achievable through the electrification of services and other energy efficiency measures. *(Also see the Buildings Plan, e.g. regarding retrofitting existing building stock).* • Phase out all natural gas use and fossil-based liquid fuelled transport: replaced by transport powered primarily by renewable-generated electricity, with a small amount of biofuel used in rural areas and emergency services.
Buildings Plan	• Reduce the operational emissions of existing building stock to zero emissions by 2022 (i.e. achieved within 10 years). • Halve residential energy usage, e.g. via full insulation retrofit, efficient window glazing, better shading, and other measures such as lighting upgrades, and more efficient appliance. • Go gas-free: electric heat pump heating for space heating, cooking with induction cooktops, and heat pump hot water; • Turn Homes into 'power stations' via rooftop solar energy – most homes generate more power than they use. • Aim to halve non-residential energy use, and install 2.5 GW of rooftop solar on non-residential buildings.

More information is available at: https://bze.org.au/zero-carbon-australia-2020

Low-carbon Growth Plan (ClimateWorks Australia)

This report provides an economy-wide 'low-carbon growth plan' for Australia, which outlines a plan for reducing greenhouse gas emissions by 25 per cent below 2000 levels by 2020. This plan focuses on profitable opportunities that require a combination of a carbon price and other targeted actions. It is based on the McKinsey & Company greenhouse gas abatement cost curve methodology.

Buildings

- Opportunities include: reducing oversized and unnecessary equipment, decreasing energy losses from open refrigeration and insufficiently insulated ovens, improving the efficiency of appliances and equipment, replacing electric water heaters with gas and solar-powered water heaters

Power

- Opportunities include: onshore wind, coal to gas shift, solar thermal with storage, improved coal and gas power plant thermal efficiencies and reduced transmission and distribution losses

Transport

- Opportunities include: improving the fuel efficiency of petrol- or diesel-fuelled cars and trucks, e.g. decreasing the accelerating and rolling resistance and weight of the vehicles

Industry

- Opportunities include: energy efficiency through improved control systems and processes, reduction of duplicated or oversized equipment, upgrade of motor systems, decrease of energy losses in boilers and steam distribution systems, and waste heat recovery

Forestry

- Opportunities include: reforestation, including commercial timber forestry and on-farm reforestation such as planting 1–2 per cent of productive farmland with trees in the form of windbreaks or plantings along waterways and as tree islands to shade livestock, reducing first-time deforestation and reducing clearing of regrowth

Agriculture

Opportunities include: soil carbon sequestration such as increasing the prevalence of deep rooted perennial grass species, optimising grazing intensity and timing, and reducing salinity and erosion through revegetation, and reducing livestock emissions through using higher quality feed and anti-methanogenic vaccines

The 2011 update of the plan emphasised the role of carbon pricing and other government policies. The modelling found that a carbon price of $20 to $30/tCO would have a very significant impact, respectively doubling and nearly tripling the volume of profitable abatement opportunities. It also found that many opportunities for additional policies are needed, such as introducing standards for new buildings and equipment, information programs and R&D investment.

For more information see: http://www.climateworksaustralia.com/project/national-plan/low-carbon-growth-plan-australia